

Feasibility Study of Electric Bicycle Sharing in the Xiasha

District of Hangzhou, China

An Interactive Qualifying Project

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Abstract

Traffic and pollution are persistently growing problems in Hangzhou, one of the oldest and most modern cities in China. To offset this, Hangzhou Omnipay Co., Ltd. sponsored this project to determine if an electric bike sharing system would be feasible in the Xiasha District of Hangzhou. If the system proves effective, Omnipay can implement it in the rest of the city. Electric bikes produce no direct emissions and occupy less road space than automobiles, circumventing the common issues of cars. This project used various onsite research techniques including a survey, focus group, and interviews to discern if there is adequate demand for this system and what its environmental influence may be. This report concludes that an electric bike sharing system would be feasible.

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Thank you Omnipay!

Executive Summary

Introduction

Subway, bus, rail, taxi, and even bicycle sharing systems have become the standard for public transportation in cities across the world; however, electric bicycle (e-bike) sharing systems have yet to make this list. E-bike sharing poses a whole new set of obstacles that manual bike sharing systems do not face: power supply, charging time, and battery replacement to name a few. Despite the additional complications, Copenhagen, Denmark, a city known for its bicycle culture, dropped its manual sharing system in 2012 and implemented an e-bike share, Bycyklen, in December 2013. Madrid, Spain also began operation of its own e-bike sharing system, BiciMAD, in June of 2014. China, with two of the largest manual bicycle sharing systems in the world (Hangzhou and Wuhan), has not yet tested an e-bike share program. One possible reason for this absence: the lack of an existing system in China to serve as a model.

With a population of approximately eight million people, the city of Hangzhou is in the process of upgrading its transportation system. The city has integrated subways, buses, taxis, and a bicycle sharing program with over 60,000 bikes to provide a fluid transportation network. Hangzhou is the richest city in Zhejiang Province, and has a highly awarded, self-sufficient bicycle sharing system. Hangzhou Omnipay Co., Ltd. (Omnipay), the project sponsor, provides user interface for the current bike sharing system, including equipment and software. Omnipay hopes to support green transportation by implementing an e-bike sharing system in the Xiasha District of Hangzhou. This project investigates the feasibility of e-bike sharing in Xiasha.

Electric-Bike/Bike Sharing

To understand the characteristics of existing e-bike sharing systems, we considered three programs from around the world: Bycyklen, BiciMAD, and cycleUshare, a small scale pilot system on the University of Tennessee-Knoxville campus. Each system provided us with valuable information such as pricing rates, issues, and probable infrastructural requirements. For example, Bycyklen's system charges higher subscription rates with lower hourly fees, while BiciMAD charges lower subscription rates with higher hourly fees. Both Bycyklen and BiciMAD offer incentives to users for returning bikes to low occupancy stations to reduce maintenance costs of transporting e-bikes between stations. CycleUshare provided insight about including both manual and electric bikes in the same station, as well as information about pedal assist e-bikes- the type of e-bike used in sharing systems. Considering the cities of Copenhagen and Madrid, both have accessible bike lanes throughout the city.

In addition to e-bike sharing systems, we also researched manual bike sharing systems within China. We found the elements of accessibility in Shanghai's program particularly relevant to our study. The strategic placement of stations in and around universities popularized the system to the point that operators set time limits for usage per person. Hangzhou's current bike sharing system exemplifies the model for a successful program,

with sustainable operations and stations placed at least every 500 meters. A transportation card allows users to pay for the bike sharing system, as well as bus, taxi, and subway services.

Xiasha District

Our feasibility study focused on the Xiasha Higher Learning Garden (XHLG), an education district with over 190,000 students, in Hangzhou. The XHLG represents the cluster of 14 universities in the Xiasha District, a sub-city center of Hangzhou. The Hangzhou metro line has two stops on Line 1 that connect the XHLG with the rest of the city. A planned extension of the line will link schools on the east side of XHLG with greater Hangzhou by subway.

E-Bikes and the Environment

With private car owners on the rise in China, pollution caused by transportation has increased. E-bikes provide a cleaner alternative to cars and other gas burning vehicles, like motorcycles and mopeds. Because electricity powers the bike's battery, an e-bike does not directly produce air pollution. However, since coal plants supply the primary source of electric power to the grid in China, e-bikes will indirectly pollute the environment, although not within the city. Lithium Ion batteries are commonly used by e-bikes, and have potentially harmful environmental effects if not disposed of properly.

Goal and Objectives

The goal of this project was to determine the feasibility of an e-bike sharing system focused on students in the Xiasha District of Hangzhou. To attain this goal, we set the following objectives:

1. Determine if there is student demand in Xiasha for e-bike sharing
2. Identify the environmental benefits and costs of e-bike sharing
3. Determine if Xiasha has the appropriate infrastructure to support e-bike sharing

Methodology

In order to achieve our objectives, our methodology consisted of various techniques, including: a survey, a focus group, direct participation and observation, interviews, and mapping. We surveyed 680 students at five different universities to reach a 95% confidence level with +/-3% error. The survey allowed us to determine if students in the Xiasha Higher Learning Garden were interested in e-bike sharing, as well as identify their environmental concern and willingness to pay for an e-bike sharing system. The focus group, with 10 students from Hangzhou Dianzi University, supplemented our findings from the survey by providing a more in depth account of reasons for student interest and concern. We used direct participation and observation to gain a deeper understanding of the current public transportation network in the Xiasha District as well as other districts in Hangzhou. We furthered our knowledge of the current bicycle sharing system by observing the stations with Omnipay, who provided answers to questions concerning the operational elements of the stations. Mapping allowed us to visualize the public transportation stations currently available to students in the Xiasha District.

Findings

The key findings from our report include:

- There is student interest in e-bike sharing
- Safety, price, and social implications are factors that might deter students from using e-bikes
- E-bike sharing can benefit the environment in the Xiasha District
- The positive influence e-bikes have on the entire environment is partially dependent on the types of transportation that e-bikes displace.
- The Xiasha District has the infrastructure capable of supporting an e-bike sharing program
- The optimal location of e-bike stations are at existing manual bike sharing stations

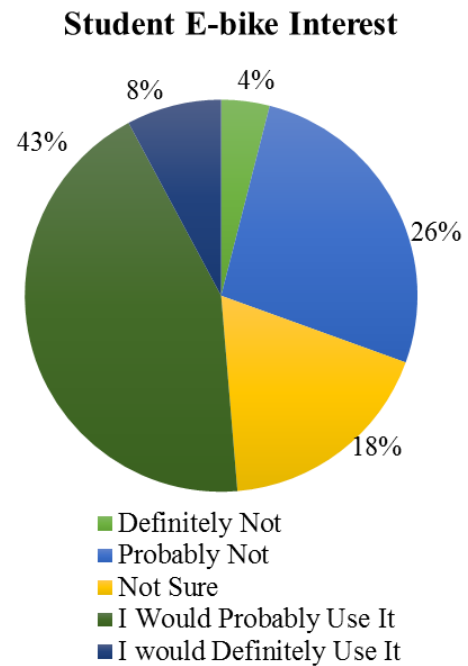


Figure 1.1: Student Interest in E-Bike Sharing

Student Interest

There is student interest in e-bike sharing in the Xiasha District of Hangzhou. This claim is supported by the 51% of students who responded that they would, either probably or definitely, use e-bike sharing as shown in Figure 1.1. In order to understand why e-bike sharing did appeal to 30% of students, we identified the main concerns that students expressed: safety, price, and aesthetics.

Almost a quarter of surveyed students (23%) felt that e-bikes were dangerous, selecting a 1 or 2 on a scale of 1 (Dangerous) to 5 (Very Safe). In addition, e-bike safety ranked highest among reasons for low interest in e-bikes, with over 200 responses, and general travel safety was a deciding factor in choosing a mode of transportation. Consequently, e-bike safety is worth considering when implementing an e-bike sharing system.

Price is also a determining factor. A deposit price of 1500RMB is too high to attract student interest, and much higher than what other e-bike sharing systems charge. Offering a lower deposit fee or allowing payment via a multifunctional card like the citizen card might overcome the price barrier. Also, students in both the focus group and survey were willing to pay higher rates per hour than offered by the manual bike sharing system. Offsetting deposit price with higher hourly rates might encourage student interest.

The presence of advertisements and painted color can make rental bicycles unappealing to students. The students in the focus group acknowledged that the appearance of the current sharing system's bikes were unappealing to them. The color, advertisements, and basket all acted as deterrents for student use. Therefore, a more aesthetically pleasing appearance for e-bike might increase student interest in the program.

Environmental Benefit

E-bike sharing can benefit the environment in the Xiasha District by offering an alternative mode of transportation that does not directly emit greenhouse gases into the city. The survey determined that 31% of the student population uses a private car and that 83% of daily car users consider the environment important (a 3, 4, or 5 on a scale of 1 to 5, not important to very important). Of the schools we surveyed, the Zhejiang University of Finance and Economics represented the largest percentage of car users. This makes it a prime location

for a new e-bike system to displace private automobiles that emit pollutant into the city environment.

The survey also revealed that walking is the most used mode of transportation by students. With 40% of the 93% of students who walk daily expressing interest in e-bike sharing, walking would be the most displaced mode of transportation by e-bikes. Because walking is the most environment friendly travel method, e-bikes could perhaps have a negative effect on the environment. However, this negative impact would not be in the Xiasha District, but rather at the location of the power plant.

Infrastructure

The Xiasha District has the infrastructure capable of supporting an e-bike sharing program. The optimal location for e-bike sharing stations are at current manual bike sharing stations because these station have a connection to the power grid and most are near other public transportation stations. Using these current bike stations can provide power to charge e-bikes and help e-bike sharing integrate into the current transportation network.

Convenience was the most influential factor for students choosing a mode of transportation. Station placement should therefore consider the accessibility of stations to students. E-bike stations should be within walking distance of campuses and connect students to other modes of transportation like the subway to increase the convenience of the system.

Conclusion

The intent of this project was to determine the feasibility of an electric bicycle sharing system in the Xiasha District of Hangzhou. In order to accomplish this goal, we identified three objectives to organize methods and provide a framework for discussion. By researching student demand for electric bikes, we determined if students would be a viable user base for the system. Through understanding the environmental long and short effects of e-bikes, we determined if Omnipay could use environmental benefits to gain governmental support. And by considering the current transportation infrastructure, we determined if Xiasha could support the addition of e-bikes into its transportation network. The project findings lead us to the following conclusion: An e-bike sharing system is feasible in the Xiasha District of Hangzhou.

The findings show that there is sufficient potential demand in Xiasha for an e-bike sharing system. Over half of the population would likely use the system, enough to justify its implementation. Despite this, there are several aspects that might impede the number of people willing to use the system, including: price, safety, and style. The suggested deposit fee of 1500RMB is likely too high for many students, and a lower price would encourage more participants. We recommend that Omnipay consider two potential options to offset the deposit price: charge for the first hour of use or offer subscription payment plans. In regards to students' safety apprehension, we suggest promoting safety by installing speed restrictions on the electric motor and offering helmets at e-bike stations. To address the style concerns brought up in the focus group, including color scheme, advertisements, and baskets, we recommend the following: detachable baskets, a survey of student color interest, and advertisements focused at the rider rather than the observer.

By displacing automobiles, e-bike sharing can improve traffic conditions and air quality in Xiasha. E-bikes take up less road space and have minimal gas emissions when compared to automobiles. Thus Omnipay should implement the new system at universities with a high percentage of student drivers. E-bike sharing will complement the current bike sharing network, offering current bike share users the advantage of pedal assistance when traveling long distances. E-bike sharing would not benefit the environment if it displaces walking, the most environmentally friendly mode of transportation. If students participate in

e-bike sharing, they may be more inclined to continue renting e-bikes as professionals; thereby e-bike sharing will reduce the number of automobiles in the long term.

We concluded that the Xiasha District has the appropriate infrastructure to support an e-bike sharing program. Xiasha not only has an extensive public transportation network including a subway line, buses, bike sharing, and taxis, but its manual bike sharing stations also have connections to the power grid. This means that if Omnipay implements an e-bike sharing program in the Xiasha District, it can integrate e-bikes into the current manual bike sharing stations to charge the e-bikes and connect them to the existing transportation network. Because of this, we recommend that Omnipay optimize e-bike sharing locations by incorporating them into existing bike sharing stations. We suggest that consideration also be given to station placement within walking distance of universities to accommodate the large percentage of students who walk daily. This improves the convenience, or accessibility, of stations to students, which may increase e-bike sharing users. In addition, providing e-bike stations near subway station can help connect students to public transportation out of the Xiasha District.

In conclusion, an electric bicycle sharing system is feasible in the Xiasha District of Hangzhou. There is student demand in the Xiasha District for e-bike sharing, e-bikes have the potential to be positively beneficial to the environment in Xiasha, and the Xiasha District has the appropriate infrastructure to support an e-bike sharing system. The Xiasha District has the capability of producing the first successful e-bike sharing system in China, which can perhaps serve as a model for other cities.

Recommendations

Our main recommendations are summarized as follows:

- Prioritize convenience, price, safety, and style when implementing an e-bike sharing system.
- Consider some e-bikes with optional baskets, a more stylistic color, and fewer advertisements to encourage more student users.
- Implement at locations with the highest car user population.
- Plan accessible stations near campus to maximize convenience for students.

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We are Pokémon Masters

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Chapter 1: Introduction

China's economy has grown startlingly fast in the last few decades. Although heralded as some of the best in the world, China's transportation systems have inhibited its economy (Kang & Biao, 2012). Like many other countries around the world, China is tackling traffic jams and the air pollution caused by the vast number of vehicles on the road through the implementation of more public transportation. Even so, people value the demonstration of wealth offered by private vehicles (Naess, 2012). Consequently, public transportation systems do not satisfy the desire for private transportation (Kang & Biao, 2012; Naess, 2012). Private automobiles enable people to travel long distances to facilities of their choosing without transferring between different modes of public transportation (Naess, 2012). Researchers attribute the increase in private automobile ownership since 2004, when they became legal, to the demonstration of wealth and/or travel efficiency (Naess, 2012; Weinert, Ogden, Sperling, & Burke, 2008). In other countries, electric bicycle (e-bike) sharing acts as a travel alternative to reduce car users in the city (GoBike, 2014; Laursen, 2014 a; Laursen, 2014b; Mirani, 2014).

Hangzhou, located in the Zhejiang Province with a population of roughly 8 million, established the first successful bicycle sharing system in mainland China in order to help reduce air pollution and traffic congestion (Larsen, 2013; Li, 2014; Shaheen, Zhang, Martin & Guzman, 2011). In addition to promoting green transportation, the city designed the system to resolve the first/last mile problem of public transportation (Mobiprize, 2013). We define the first/last mile as the distance between the initial or final destination and public transportation. For example, people might avoid the subway if they have to walk a mile to their final destination after exiting the station. While the bike sharing system continues to function successfully, Hangzhou's residents may still desire a mode of transportation that balances safety, mobility, physical exertion, and acts as a status symbol (Naess, 2013). Already boasting one of the largest manual bike sharing systems in the world, Hangzhou could consider following in the footsteps of other bike sharing cities like Copenhagen, Denmark, and Madrid, Spain, and introduce e-bikes into their public transportation network. There is no such existing model in China, however, to serve as a model for Hangzhou.

As one of the wealthiest Chinese cities, Hangzhou presents itself as a city financially capable of implementing innovative techniques into its public transportation system. Bycyklen, in Copenhagen, and BiciMAD, in Madrid, are model e-bike sharing system

serving populations of 1.25 and 6.5 million respectively (Denmark, 2014; Madrid, 2014). These e-bike sharing systems are also two of the most recent e-bike projects, both opening to the public within the past year. A few years older, and on a significantly smaller scale, the University of Tennessee-Knoxville's cycleUshare is an example of a studied e-bike sharing system (Langford, Cherry, Yoon, & Smith, 2014).

Despite the differences in scale, Hangzhou can still learn from the successes and failures of these systems. Although scholars have analyzed the characteristics of manual bike sharing systems in Hangzhou and other cities in China to identify their advantages and disadvantages, but no one has researched e-bike sharing feasibility in China. The existence of e-bike sharing systems in Europe and North America prove that these systems can function, but what makes them feasible and financially viable remains unclear. Also, the context in Hangzhou is inevitably different from Europe and North America.

The goal of this project was to determine the feasibility of a successful electric bicycle sharing system in the Xiasha District of Hangzhou. The project focuses on the 190,000¹ students in the Xiasha Higher Learning Garden (XHLG), the largest education center in the Zhejiang Province (1Hangzhou.com, 2009). Hangzhou Omnipay Co., Ltd. (Omnipay), the project sponsor, provides user interface for the current bike sharing system, including equipment and software (Aragon, Humbaraci, & Papotto, 2011; C. Huang, personal communication, November 4, 2014). To achieve our goal, we determined if there is sufficient demand, identified the environmental benefits and costs, and determined if Xiasha has the appropriate infrastructure for supporting an e-bike sharing system. Our methodology included interviews, a survey, a focus group, direct observations and participation, as well as transportation mapping. We synthesized the data to determine the feasibility of an e-bike sharing system in Xiasha. Omnipay may use the findings, conclusions, and recommendations to gain government support for e-bike sharing.

¹ Sum of school populations as given by: China Jiliang University, 2014; Hangzhou Dianzi University, 2014; Hangzhou Normal University, 2014; Hangzhou Vocational & Technical College, 2014; Hangzhou Yuying College of Vocational Technology, 2014; School of Economics and Trade, 2014; Zhejiang Economic & Trade Polytechnic, 2011; Zhejiang Financial College, 2014; Zhejiang Gongshang University, 2014; Zhejiang Police Vocational Academy, 2014; Zhejiang Sci-Tech University, 2014; Zhejiang University of Finance & Economics, 2014; Zhejiang University of Media and Communications, 2014; Zhejiang University of Water Resources and Electric Power, 2014

Chapter 2: Background

The city of Hangzhou has developed one of the largest bicycle sharing systems in the world (Lebetkin, 2013), but does this mean that the city can successfully implement an electric bicycle sharing system too? To help determine the feasibility of introducing electric bicycle sharing in Hangzhou, this chapter discusses current bicycling sharing systems in China, the United States, and Europe. We explore the elements of feasibility, including: economic, political, environmental, health and social effects of electric bicycle sharing.

2.1 Electric Bicycle Sharing Markets around the World

Hangzhou has demonstrated how successful manual bike sharing can be in a Chinese city, but China has never tested an electric bike (e-bike) sharing service (Larsen, 2013). To assess the feasibility of an e-bike service in the Xiasha District of Hangzhou, we begin by describing other electric bike sharing services around the world.

2.1.1 United States of America: cycleUshare

Known as cycleUshare, America's first e-bike sharing program started service in 2011 on the University of Tennessee- Knoxville (UTK) campus (Langford, Cherry, Yoon, Worley, & Smith, 2013). Implemented for a population much smaller than Hangzhou, with under 40,000 students, staff, and faculty, the system provided a chance to study both bike and e-bike sharing as well act as a green initiative on campus (University of Tennessee-Knoxville, 2014; Ji, Cherry, Han & Jordan, 2013).

Although piloted on a very small scale, researchers highly analyzed the cycleUshare system at UTK throughout its active period (2011-2014). As part of a university funded study, one of the goals of the project consisted of evaluating the feasibility of the e-bike sharing system in both technical and business model terms (cycleUshare, 2014; Hancock, 2014). In addition to feasibility, researchers planned to study user behavior, safety, physical health, environmental effects, willingness to pay, and user perception during the research project. In an interview with Christopher Cherry, one of the leading researchers, we learned that the study of pricing never panned out for experiment (C. Cherry, personal communication, October 11, 2014). The system remained active through mid-2014 when UTK cut funding for the program (Hancock, 2014). Research grants initially supported the project, but without another source of financial support the system could not continue to run

(WBIR, 2014). The next steps remain unclear; however WBIR, a local news network, wrote that the cycleUshare researchers wanted to share their data and studies with other universities.

Even though UTK discontinued cycleUshare, its experience and system holds lessons for others. To begin with, cycleUshare dispensed both manual and electric bikes at the same station (Langford, et al., 2013). As shown in Figure 2.1, the service had two stations, the Presidential Court station and the University's Agricultural (Ag) Campus station. The Presidential Court station opened in August 2011 near the residence halls, and the Ag Campus station started operating in April 2012 close to a large parking lot and academic buildings. By the end of 2012, the Presidential Court station received 91% of all trips by all users. Because the system only had two stations, cycleUshare required that users return the bikes to the same station from which they retrieved them. This limited the types of trips taken. With a total of 14 e-bikes and 6 manual bikes, each station had 10 vehicles and 15 batteries available for distribution (Ji, et al., 2013).

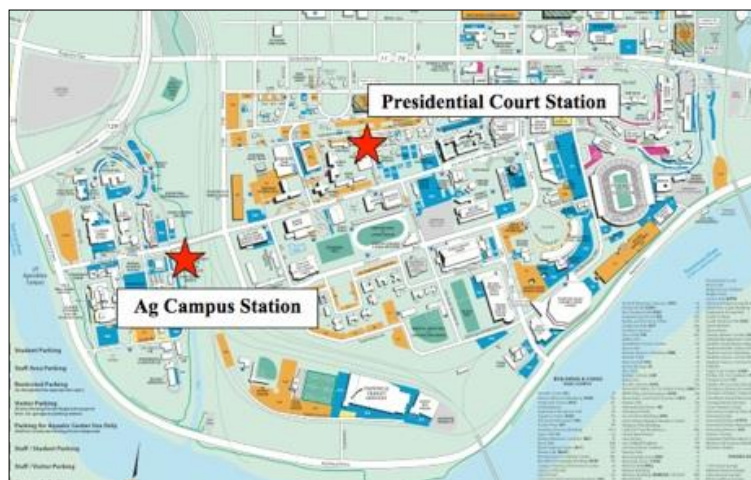
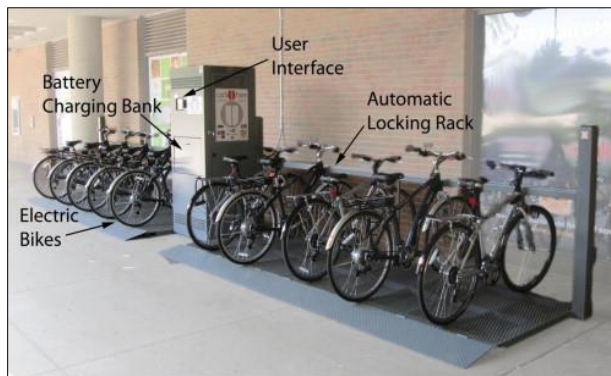


Figure 2.1: Map of cycleUshare Stations (cycleUshare, 2014)

Of the two stations, the electric grid powered the Presidential Court station and photovoltaic panels generated solar power for the Ag Campus station. Figure 2.2a provides details of the layout of the Presidential Court station. Note the battery charging bank and the user interface. The interface allows registered users to retrieve an e-bike battery from the charging bank. Figure 2.2b depicts the Ag Campus station, displaying the photovoltaic panels on the roof of the station. The Ag Campus station operated from 6:00 AM to 10:00 PM and the Presidential Court station dispensed bikes 24 hours per day.



(a) Presidential Court station



(b) Ag Campus station

Figure 2.2: UTK's cycleUshare Stations

All students, staff, and faculty could enroll in the system; however, researchers limited the number of applicants accepted to 93 users to prevent the system from overloading (Langford, et al., 2013). CycleUshare introduced users gradually into the program to monitor the system and analyze problems. Users could rent both types of bikes free for up to four hours with no penalty for going over time. Usage did vary with the weather, and Langford noted that riders decreased during the colder months, but increased when the weather got warmer. Researchers recorded close to 900 bike rentals during an eight month time frame with electric bikes representing two-thirds of that number. The study showed that speed and mobility influenced a user's decision to use the system and that e-bikes and bikes displaced walking the most.

The cycleUshare e-bikes required the user to pedal in order to receive assistance from the motor (Langford, et al., 2013). The pedal assist e-bike functions similarly to a manual bike both in operation and appearance, with the added benefit of electromechanical power to assist during use (Cherry, Worley, & Jordan, 2010). Lithium ion batteries powered the e-bike (Ji, Cherry, Han & Jordan, 2013). A sensor near the pedal measured the rider's effort. When the battery or motor failed, the e-bike required more physical effort than a manual bike due to the additional weight (Langford, et al., 2013). Figure 2.3 details the e-bike used by the cycleUshare program, showing the location of the pedal assist sensor, the user interface, the battery and other components of the e-bike. The design of the e-bike allowed the user to remove the battery off the back of the bike and place it in the charging bank (refer to figure 2.2a) (Langford, 2013). This battery provided the power for the motor. The user control

interface let riders choose the level of motor assistance they wanted to receive. Figure 2.3 also shows how similar pedal assist e-bikes are to manual bikes.



Figure 2.3: Pedal Assist E-Bike (Ji. et al., 2013)

An interactive touch screen at both stations acted as the user interface (Langford, et al., 2013). Only UTK students, staff, and faculty could access the system, and they used their university identification card to retrieve the bicycle or e-bike. The user interface proved one of the most problematic parts of the pilot study. In order for the system to function properly, clients needed to use their identification card to check out the bike, and upon returning, check-in the bike. Improper check-in caused the system to incorrectly track the location of the bikes. In addition to working on the check-out/check-in problems, the developers updated the software throughout the study to work out minor flaws.

Before becoming inactive, researchers studied the operational concepts of the system, including a simulation study that tested slow and fast charging systems (Ji, et al., 2013). The simulation showed that the required number of batteries remained almost constant regardless of charging speed. Researchers also concluded that trip rate, trip length, and activity duration had a significant effect on the number of e-bikes and batteries needed for the system. In addition, the study found that activity duration had the greatest effect on the battery of all the factors. As a result, the authors suggested that the system limit activity duration by setting a travel limiting cost.

The UTK cycleUshare sharing system is the most studied e-bike share system to date. The system provided information regarding operational concepts as well as different station types and usage characteristics. However, cycleUshare only provides a limited understanding of e-bike sharing because it lacked a pricing component.

2.1.2 Spain: BiciMAD

In late June of 2014, Madrid opened its e-bike sharing system, BiciMAD. (Gonzalez, 2014 and Laursen, 2014b). By providing e-bikes, the city hopes to take cars off of the road and reduce congestion in the city. Currently the system, launched by Bonopark, includes 1,560 e-bikes, 3,126 anchors, and 123 stations spread across the city (BiciMAD, 2014). The anchors charge and secure the e-bikes at the stations. Figure 2.4 shows a map of the locations of the 123 BiciMAD stations. Users can find a station at least every 300 meters, providing many options to pick the station closest to them. For a larger version of the map, please refer to Appendix E.

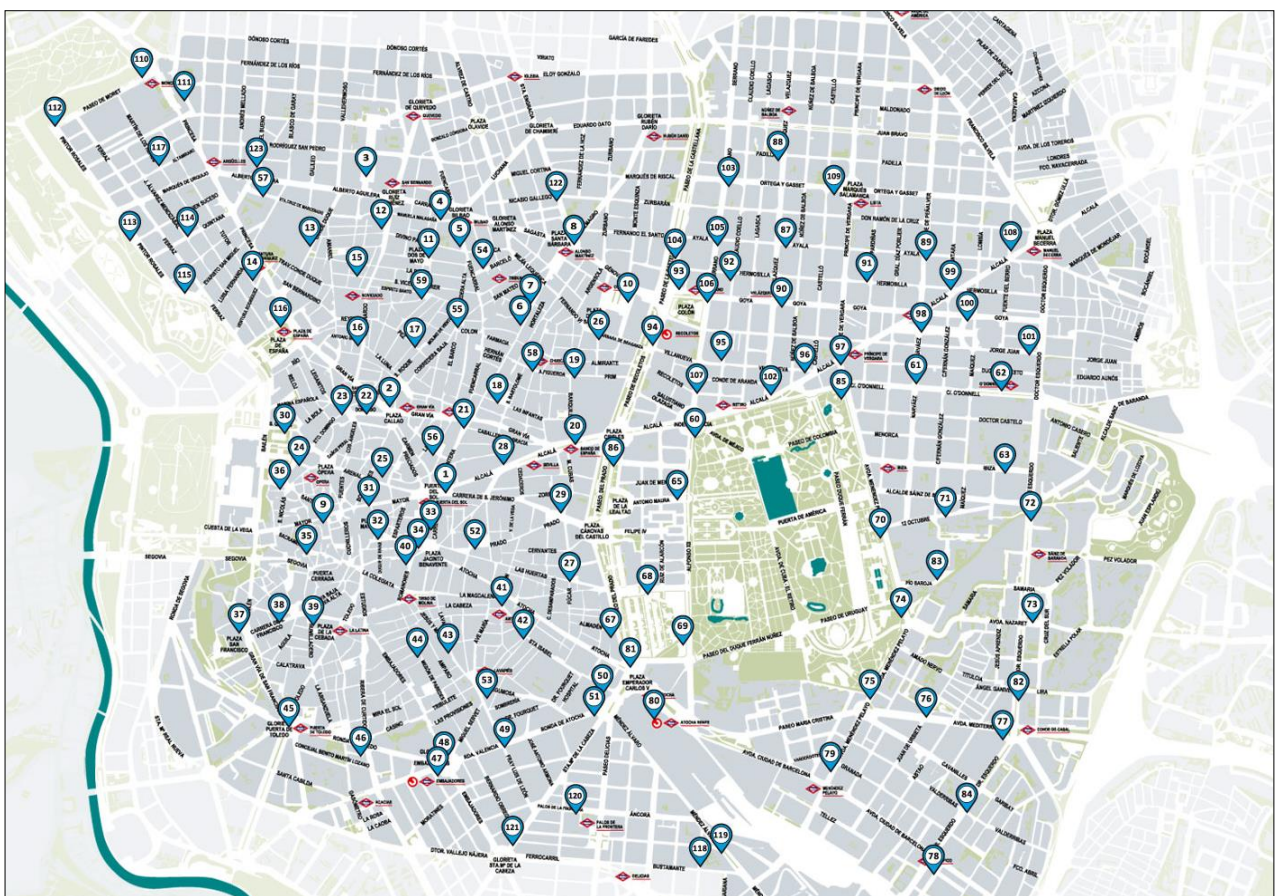


Figure 2.4: Map of BiciMAD Stations (BiciMAD, 2014)

BiciMAD's service operates 24 hours a day, every day of the year (Bonopark, 2014). Figure 2.5 shows the interactive display kiosk, also referred to as a "totem," available at every station that allows users to pick up or purchase a pass, reload their balance, reserve an e-bike, and report incidents (BiciMAD, 2014; Bonopark, 2014).



Figure 2.5: BiciMAD Totem (BiciMAD, 2014)

The cost of renting a bike depends on the type of user: annual subscriber or day user (BiciMAD, 2014; Bonopark, 2014). Currently, users can only sign up for the annual subscription and it remains unclear when the casual user option will be available. Table 2.1 depicts the different rates for the two types of users. The system offers annual subscribers lower hourly rates, with no required deposit. When available, BiciMAD will require a relatively large deposit and higher rates per hour from those who wish to use the system without the yearly subscription. Ten, one-hour trips as a casual rider (~155RMB) is the equivalent of 5 one hour trips for an annual user with a Regional Transportation Subscription (~160RMB).

Table 2.1 Annual and Day-User Vending Prices (BiciMAD, 2014; Bonopark 2014)

| Annual user | Type | Annual Fee | First Half Hour | 0.5-2 hours | After 2 hours |
|--|--|----------------------|------------------|----------------------------|----------------|
| | With Regional Transportation Subscription | €15.00 (~117RMB) | €0.50 (~3.89RMB) | €0.60/half hour (~4.66RMB) | €4.00 (~31RMB) |
| | Without Regional Transportation Subscription | €25.00 (~194RMB) | | | |
| Occasional/ Casual User (Currently Unavailable) | Type | Deposit ¹ | First Hour | Second Hour | After 2 Hours |
| | 1 Day | €150.00 (~1150RMB) | €2.00 (15.5RMB) | €4.00 (~31RMB) | €4.00 (~31RMB) |
| | 3 Days | | | | |
| | 5 Days | | | | |
| ¹ Deposit charged to the user's credit card, returned upon payment of all charges | | | | | |

Renting an e-bike from the BiciMAD system costs more than other forms of public transportation in Madrid (Laursen, 2014b). Because the system does not plan to compete with other forms of public transportation that pedestrians use, BiciMAD does not consider this higher relative cost for e-bike use an issue. E-bike sharing intends to attract and reduce the number of car-commuters. Users can offset the cost of borrowing an e-bike by observing the credit system offered by BiciMAD. By returning e-bikes to low or renting from high occupancy stations, users can receive the equivalent of 0.77 RMB back to their account (BiciMAD, 2014; Laursen, 2014b). Reserving an e-bike also grants users the same amount. This system is mutually beneficial to the user and program operator because it provides credit to the user and reduces maintenance costs of transporting e-bikes by the operator.

For customers who subscribe annually, BiciMAD deducts fees from their annual card balance (BiciMAD, 2014). Subscribers need to add at least €10 (~77RMB) to their card at a time. If they run a negative balance, they will be unable to use the BiciMAD service. When the casual user service becomes available, consumers will be able to select a card for 1, 3, or 5 day periods. The card itself is free, but to prevent theft, customers have to make a “pre-authorization” or safety deposit of €150 (~1150RMB) as listed above in Table 2.1 above. The minimum age requirement of a user is 14 years with parental permission, or 16 years without parental permission (BiciMAD, 2014).

The e-bikes used by BiciMAD weigh in at 22 kilograms, and have a battery that can power the bike for up to 18 hours or 70 kilometers (Gonzalez, 2014). Also included on the e-bikes are global positioning system (GPS) tracking devices (Laursen, 2014b). Within the first couple months of operation, BiciMAD recovered nineteen stolen e-bikes because of the GPS. This side of the technology has proven very useful; however, the user interface has experienced issues involving hackers who compromised the system (BiciMAD, 2014).

2.1.3 Denmark

Copenhagen beta-tested their e-bike sharing system, Bycyklen, in the fall of 2013 and implemented a full system in December 2013 (Laursen, 2014a). The city decommissioned its original, coin-operated manual bicycle sharing program of the same name before the implementation of e-bikes (Laursen, 2014a; Mirani, 2014). Because of this background, the program operator, Cykel DK, anticipated some of the difficulties that the new system might experience.

A smart interface tablet, positioned between the handle bars of each e-bike, is a key feature of the system (Bach, 2014; Bycyklen, 2014; Larsen, 2014a; Lewington, 2014). Claimed to be vandal proof and equipped with a GPS, the tablet allows users to reserve, pay, and navigate the e-bikes. The navigation feature shows main tourist destinations in the city, and the tablet also lists information via a website known as Rejseplanen, which translates in English as “The Itinerary.”(Bach, 2014). Rejseplanen allows users to plan trips and provides information about schedules and times for a variety of different transportation methods (Rejseplanen, 2014). Also, when riding the e-bike, users can select the level of assistance they wish to receive from the motor on the tablet (Lewington, 2014). The rider can select no assistance or one of four levels (neutral, city, countryside, and hill climb respectively).

In addition, Cykel DK has further developed the software to enable users to book the bikes using their phones and computers (Bycyklen, 2014). Riders can also check the website or phone application to determine the availability of bikes at nearby locations (Bycyklen, 2014; Bach, 2014). If one station is receiving more reservations than others, the company offers credit to nearby riders who return their bikes to that particular station. The current pricing of the system is shown in Table 2.2. Single journey riders do not pay a monthly fee, however, the system charges them hourly fees four times higher than subscriber rates. The hourly rates do not include credit card fees. Also, the system charges subscribers before each month of their subscription period.

Table 2.2 Bycyklen's Rates (Bycyklen, 2014)

| User | Monthly Rate | First Half Hour | Rate per Hour |
|----------------|---------------|-----------------|---------------|
| Subscriber | 70kr (~72RMB) | Free | 6kr (~6RMB) |
| Single Journey | N/A | N/A | 25kr (~26RMB) |

Compared to BiciMAD's system, the yearly cost of subscribing to Bycyklen runs much higher. Bycyklen charges approximately 870 RMB/year versus BiciMAD, which charges almost 200 RMB to annual users without a regional subscription (or almost 120 RMB for those with the subscription). However, the price of the first half hour is free in Denmark, while it is close to 4 RMB in Spain for the same duration of time. Similarly, the rate per hour for Bycyklen is 6 RMB while BiciMAD charges 4.66 RMB per half hour, and 31 RMB/hour when e-bike use continues beyond 2 hours. Bycyklen has a higher base rate with lower hourly rates, while BiciMAD operates with a low base rate and higher hourly rates. Because both of these systems are almost a year or younger, determining the advantages and disadvantages of each pricing system in terms of effect on users and profit is difficult to achieve at this time.

In addition to the monthly and hourly rates, Bycyklen also charges users various other fees. Table 2.4 depicts these fees, including booking, deposit, and ending outside of a docking point or zone. These fees could increase the cost of using Bycyklen, and unlike BiciMAD which rewards users for making reservations, Bycyklen charges its users to book a bike in advance. Bycyklen's user policy also documents fees associated with not returning the e-bikes to stations. For example, the system charges users ~51RMB who return e-bikes to a station with available docking points but do not properly park and lock in one. However, the deposit for using an e-bike in Copenhagen is less than half of what Madrid's system charges.

Table 2.3 Bycyklen's Other Fees (Bycyklen, 2014)

| Event | Fee |
|--|------------------------------------|
| E-bike not returned to station (but still locked) | 200kr (~207RMB) |
| E-bike returned to a station with available docking points but not properly parked and locked in one | 50kr (~51 RMB) |
| E-bike left outside of Copenhagen and Frederiksberg | Minimum 800kr (~826RMB) |
| E-bike left more than 100km from a station | Cost incurred to retrieve the bike |
| Booking fee | 10kr (~10RMB) |
| Booking fee for DSB Members ¹ | Free |
| Deposit | 500kr (~517RMB) |
| User exceeds 10 hours of rental | 500kr (~517RMB) |
| ¹ DSB is Danish National Railway | |

According to one source, while advertising is a common method of supporting transportation sharing systems, the city of Copenhagen will cover 60% of the Bycyklen cost (Laursen, 2014a). Niklas Marschall, CEO of Cykel DK, said this percentage is typical for public transportation and expected that users will cover the other 40% of operational costs. The same source reported the cost at 6,000 kr or about 6,165 RMB for each e-bike and its docking port and maintenance.

As previously mentioned, and similar to BiciMAD, Copenhagen offers credit to users (Laursen, 2014a). Bycyklen puts the credit towards future rides and intends to reduce maintenance costs of moving the e-bikes between the stations by providing the incentive. The tablets notify riders of a nearby stations that need more bikes. According to Matt Christensen, managing editor of Bikeshare.com, the most important part of a bike-share is availability. Therefore, offering a relatively small credit to users for returning the bikes to under-occupied stations can offset the need for shuttling the e-bikes around the city while ensuring the availability of e-bikes at high traffic stations.

By implementing e-bike sharing, Copenhagen intends to decrease the number of cars on the road, especially in the city center, as well as produce cleaner air and reduce noise (GoBike, 2014; Laursen, 2014a; Mirani, 2014). The city currently has over 390 km of designated bike lanes and supports a bicycle culture (Braw, 2014). Copenhagen now only offers bicycle parking in the square in front of parliament, and plows bikes lanes before car lanes. This is one example of how the city does not directly limit car usage, but rather supports bicycle usage.

The system is not meant to be stand-alone, but rather an extension of the current public transportation network (Mirani, 2014). In addition to e-bikes, the city transportation network also includes a subway system, buses, taxis, and a train service (copenhagen.com, 2014). The train service now permits bike riders to board with their bikes for free, furthering the support of bicycles in the city (Braw, 2014). Bycyklen plans to have 1800 or more e-bikes on the road by the end of 2014 (Laursen, 2014a; Mirani, 2014).

GoBike, the company who supplies the e-bikes, also provides the software to track battery life, location, and usage of the e-bikes. With this software, program operators collect the data every 10 seconds (GoBike, 2014; Lewington, 2014). In an interview with Lewington, Andreas Roehl, Head of Mobility and Open Spaces for the City of Copenhagen, said that the data the city collects has already given insight to average lengths of trips and speed. Roehl also stated that this data can help the city to adjust traffic signals to fit the speed of the bikes during high commute times. The bikes can reach up to 22 km/hr and a fully charged battery

should power the bike for at least a couple of hours, although the actual times varies depending on riding style (Bycyklen, 2014). This means that a user riding at top speeds could technically travel over 40 kilometers on a single charge.

There are currently twenty active stations in the Bycyklen system (Bycyklen, 2014). Unlike the BiciMAD system, the distance between the Bycyklen stations is greater than 300 meters. Figure 2.6 depicts the locations of these twenty stations within the city. For a larger version of this map, please see Appendix F. On the map below, an inch represents roughly 1 kilometer. Blue bikes represent the e-bike stations, which are located near other forms of public transportation; Figure 2.7 depicts the same area's other forms of public transportation, with "M" representing Metro, a red "S" representing S-train, a small black train representing Train, and a small black bus representing Bus. Due to the numerous public transportation stations in the area, Figure 2.7 only shows a few of the stations available for each of the types of transportation. We have included this map to show a comparison of the relative location of e-bike stations to other public transit stations. The proximity of the different types of stations show integration of the e-bike system into the public transportation network as supported by Kaiser's report (2012). While not visible on either of these maps, there are many bus stations near the e-bike stations. A map with both e-bike stations and other public transportation stations is not available at this time. Please refer to the Rejseplanen website (www.rejseplanen.dk) for a full interactive map with train, bus, and metro stations.



Figure 2.6: Compilation Map of Bycyklen Stations as provided by openstreetmap.org (Bycyklen, 2014).



Figure 2.7: Similar Map to figure 2.5 with some other public transportation stops and map scale. (Rejseplanen, 2014).

A final note about Bycyklen is the parking options for the system. While there are charging stations located around other transportation systems, if parking at one of these docking points is not available, Bycyklen has a solution (Bach, 2014; Bycyklen, 2014; Lewington, 2014; Mirani, 2014). A digital locking system allows users to lock the bike anywhere, and if they wish to return the bike they can lock it in a separate designated area by the station if no docking stations are available. As shown in the discussion of Table 2.3, if docking points are available and the bike is parked outside of one, then the user is charged a fee of 50 kr (~51 RMB) (Bycyklen, 2014).

2.2 Bicycle Sharing Systems in China

China is known as the “Kingdom of Bicycles” (Tang, 2011). Hangzhou, Beijing, Shanghai, and Wuhan, as well as other Chinese cities, have bicycle sharing systems. China has rapidly embraced transportation technology by implementing public buses and allowing private citizens to own cars. In 2003, Chinese streets had about 60 million motorcycles, 24 million taxis and buses, and less than 6 million private cars (Zhou, 2013). In 2013, there were about 135 million buses and taxis and more than 85 million private cars. In 2011, about 55 in every 1,000 people owned a private vehicle, while in 1985, only a negligible 0.27 for every 1,000 people did. Figure 2.8 shows the dramatic increase in the number of registered automobiles in Beijing, Shanghai and Guangzhou (Feng & Li, 2013). This inevitably has caused an enormous amount of traffic and air pollution.

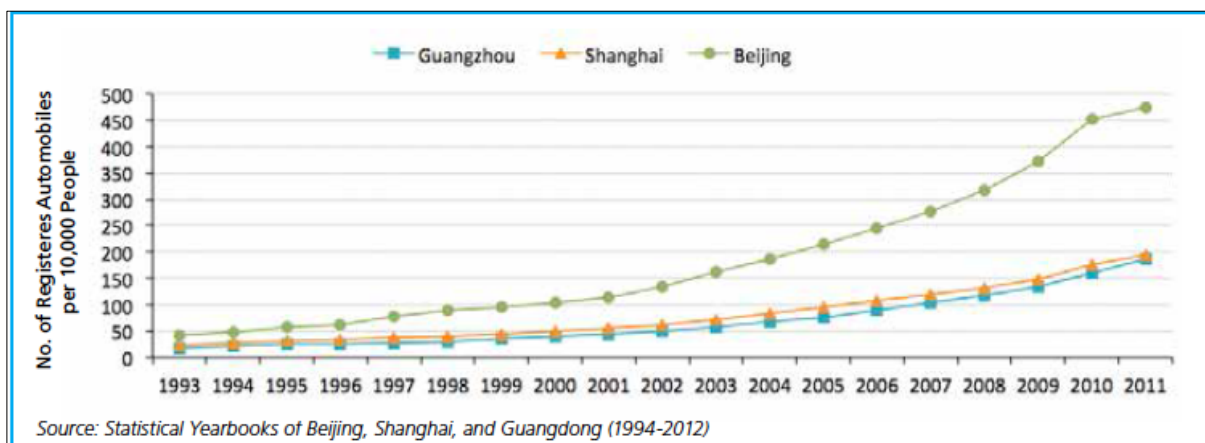


Figure 2.8: The number of registered automobiles (in 10,000's) of Beijing, Shanghai and Guangzhou (Feng & Li, 2013)

In 2005, the nation initiated a public-transit-priority strategy. Many cities invested heavily in building public transit infrastructure, and upgraded policies to encourage people to take public transportation (Feng & Li, 2013). In 2011, the government started to encourage its residents to rent bicycles instead of driving (Wang, 2012). In order to meet good traffic and air quality standards for the 2008 Beijing Olympic Games, the Beijing Municipal People's Government implemented a restriction on private vehicle use: the right to drive alternated according to whether the license plate number was an odd or even number (Feng & Li, 2013). After the Olympics Games, the government modified the policy to restrict two last digit numbers per day instead of all odd or even plate numbers (The Central People's Government of the People's Republic of China (PRC), 2009) Table 2.4 illustrates the post-Olympic Games license plate system. For example, on Monday, private cars with license plates ending in 3 or 8 cannot go on the road. Consequently, every car is off the road at least once a week (Feng & Li, 2013). The license plate numbers allowed on each day change every 13 weeks (PRC, 2009). This policy reduces traffic and exhaust emissions from motor vehicles (Chen, 2010). According to the Beijing Car Number Control Regulations, at the end of 2010, Beijing began to control the number of license plates issued in order to decrease the growth of private car ownership and further reduce traffic. In 2011, drivers had to go through "lottery" procedures to get a license plate and the city issued only 150,000 per year. Beijing also began restricting vehicles with non-local license plates from the road (Feng & Li, 2013). During peak hours, the city prohibits these vehicles from entering the 5th Ring Road, part of the network of concentric roadways that ring Beijing. As a result, many people pulled away from private cars and started to use forms of public transportation instead.

Table 2.4: Forbidden numbers of driver license in each weekday

| Sunday | Monday | Tuesday | Wednesday | Thursday | Friday | Saturday |
|--------|---------|---------|-----------|----------|---------|----------|
| Free | 3 and 8 | 4 and 9 | 5 and 0 | 1 and 6 | 2 and 7 | Free |

2.2.1 Beijing

Established in 2012, the government funds Beijing's current manual bicycle sharing program (Long, 2012). A private company, Goldenet, manages the system (Goldenet, 2012). Starting in October 2012, the bicycle sharing service opened to non-native users including migrant workers, tourists and foreigners, thereby benefiting more people and increasing its effect (Li, 2012; Wang, 2012).

Beijing's first bicycle sharing system started on June 16, 2012 (Zhang, 2013). The system initiated in the Dongcheng and Chaoyang districts and then expanded into the Fengtai, Shijingshan, Tongzhou, Daxing and Yizhuang districts. As of August 6, 2014, the system had 25,000 bicycles and more than 600 service stations. The system continues to expand gradually. By 2015, Beijing plans to have 50,000 shared bicycles and 1,000 service stations in the city center transportation hubs and commercial blocks.

However, registering for the bicycle sharing system presents a challenge. Even in the huge Chaoyang District, there are only three registration offices available (Liu, 2013). Figure 2.9 indicates these offices with red circles. The district covers 470.6 square kilometers (Chaoyang District, 2001). Furthermore, these offices are difficult to find because they are not located along the main traffic roads, and there are no apparent visual signs. There are also no telephones in the card application office, which means potential customers can only ask for directions from nearby strangers rather than from professional staff. Because registering for bike sharing takes time, government officials discourage tourists from using the bicycle sharing system.



Figure 2.9: Map of card application offices in Chaoyang District (Baidu, 2014).

To register for bike sharing, Beijing citizens must bring their ID card, a transportation IC card and a deposit of 200RMB (Liu, 2013). The transportation IC card is another transportation card that is easier to get, only requiring a 20RMB deposit. Customers can apply for cards at most traffic stations and use them for buses and subways. People without a

permanent residence card can also register using temporary residence permits along with a 400RMB deposit. Furthermore, deposit refunds require advance notice to prevent a cash shortage at the bicycle rental card application office. According to the registration staff, only six to seven people register for bicycle sharing each day.

2.2.2 Shanghai

Shanghai's manual bicycle sharing system integrates private operation with government assistance (Tang, 2011). In 2008, a free bicycle sharing plan started in Xuhui District, Shanghai to connect the campuses of the district's eight universities: Shanghai University, Shanghai Normal University, East China University of Science and Technology, East China Normal University, Shanghai University of Engineering Science, Shanghai Jianqiao University, Shanghai Jiao Tong University and Shanghai International Studies University (Fan, 2008). Students can return bicycles to stations near cafeterias, dorms, or department buildings at different universities. The system sets usage limits of 4 to 6 hours per person per day to ensure bicycle availability. Like the bicycles in Beijing, these bicycles have a GPS system that sends out signal alarms to prevent theft. The unique aspect of this inter-university system is that it requires no deposit for bicycle rental.

The current bicycle sharing system is different in each district (Chen, 2010). Districts include: Minhang, Pudong, Yangpu, Baoshan, Jingan, and Changning. Because sharing services vary, local systems are only convenient for residents but not tourists. The most successful service is in the Minhang District (Chen, 2010). It is free for the region's residents. Simply by bringing an ID and social security card, customers can apply for a "faith card" to rent bicycles for free (Chen, 2010). Registration locations are more convenient than in other cities; customers can even apply at neighborhood committees. Because of the success of the free bicycle rental system, the demand has exceeded the number of bikes available, reflected in the 1:10 bicycle to faith card ratio. Consequently, operators have postponed the card application until more bikes become available.

On the other hand, subways and buses have made bicycle sharing insignificant in Changning District (Emancipation Daily Journal, 2009). There, subway and bus routes already effectively connect schools, hospitals, shopping malls, residential areas and Zhongshan Park. However, few commuters borrow from the bicycle sharing station in Zhongshan Park, even during the morning rush hour. The key reason for the rental system's lack of popularity may be the size of its service station network for bike sharing. Zhongshan

Park only has one station. Customers must return bicycles at Zhongshan Park and pay 5RMB for 5 hours, or 10RMB for a day.

2.2.3 Wuhan

The government of Wuhan implemented a bicycle sharing system in 2009, a year after Hangzhou. As of April 2012, approximately 90,000 bikes were available for bicycle sharing with no rental fees (Lebetkin, 2013). According to the newspaper *USA Today*, Wuhan's bicycle sharing system currently has 1 bike per 100 people, while Hangzhou has 1 bike per 115 people. (Larsen 2013; Li, 2014).

Wuhan's bicycle sharing system became very popular after it started in 2009 (Wang, 2014). At its peak, the system had 1,318 service stations, with nearly 100,000 bicycles and one million rental card applicants (Wang, 2013). However, a few months later, the system became difficult to maintain due to the lack of organization and inefficient distribution of bicycles at each station throughout the system (Xie, 2014). Unused or abandoned service stations stored numerous damaged bicycles. (Wang, 2014; Xie, 2014). For instance, in the Jiangan district alone, ten stations went out of service, with no attendants or accessible bikes (Xie, 2014). This malfunction caused a decrease in public interest. Clients soon wanted to return their rental cards, because they found it difficult to rent the few remaining bikes. In response, the Jiangan district opened a rental card return office, but it could not sustain the number of customers. Even the administrator of a bike sharing station claimed that taking a taxi was more convenient than renting a bike. When compared to Hangzhou, bike sharing was less successful in Wuhan (Wang, 2014). Hangzhou's bike sharing system is a government-owned operation with federal investments. In contrast, Wuhan is a private operation with federal investments. Because Wuhan's program is a private operation, it did not have the level of government involvement necessary to effectively integrate bike sharing into the traffic planning system. As a result, bike sharing stations were not conveniently located. Furthermore, due to the lack of surveillance, degradation and theft of bikes became reoccurring problems. Even though sufficient demand for the system existed, it ultimately failed because of poor maintenance.

2.2.4 Hangzhou

Located on China's East coast, Hangzhou is the capital of the Zhejiang Province and is one of the richest cities in China (Shaheen, Zhang, Martin & Guzman, 2011). The population of Hangzhou is close to 8 million, and the total city area covers 16,596 square

kilometers (Li, 2014). There are eight districts within the city and five counties, with a population density of 480 people per square kilometer in 2008 (Government of Hangzhou, 2008). The population density is especially concentrated in areas of greater economic opportunity such as Qianjiang New City (downtown) or Xiasha (a sub-city center) (Naess, 2013; hzrb.cn, 2010). Qianjiang New City offers office and service oriented opportunities while Xiasha offers industrial employment and higher education (1Hangzhou.com, 2009).

This feasibility study focuses on Xiasha, a sub-city center with a population of 300,000 in 2010 (hzrb.cn, 2010). Known as the “Hangzhou Economic and Technological Development Zone (HETDZ),” Xiasha fosters development in various industries and the Xiasha Higher Learning Garden (1Hangzhou.com, 2009; Hangzhou.gov.cn). Xiasha has industries involved in fields ranging from machinery to high-tech chemistry and is projected to develop with a new focus on quality improvement over quantity expansion (Hangzhou.com, 2009; CIPA, 2008). Based on statements by Chengmin Sheng, the director of the administration committee of Xiasha, the administration of Xiasha prioritizes attracting investment from the “the world top 500” enterprises (CIPA, 2008). For example, Xiasha gained investments worth 115 million dollars in the 2008 Zhejiang Investment & Trade Symposium (CIPA, 2008). The district simultaneously focuses on higher education. As the largest education district in the Zhejiang Province, the Xiasha Higher Learning Garden has fourteen higher education institutions with over 190,000² students as of 2014 (1Hangzhou.com, 2009; Ming, 2010). To support its industrial and education districts, Xiasha’s transportation has also become the most convenient system of any Hangzhou sub-city center (Hangzhou.gov.cn, 2009). Construction projects, such as “33317,” continue to improve infrastructure (1Hangzhou.com, 2010). In particular, the government will construct “three bridges, three tunnels, three ways with one line, and seven city expressways” in Hangzhou as part of project 33317. This project will construct two new roads and a tunnel to connect Xiasha to downtown Hangzhou (Qianjiang New City) (1Hangzhou.com, 2010).

² Sum of school populations as given by: China Jiliang University, 2014; Hangzhou Dianzi University, 2014; Hangzhou Normal University, 2014; Hangzhou Vocational & Technical College, 2014; Hangzhou Yuying College of Vocational Technology, 2014; School of Economics and Trade, 2014; Zhejiang Economic & Trade Polytechnic, 2011; Zhejiang Financial College, 2014; Zhejiang Gongshang University, 2014; Zhejiang Police Vocational Academy, 2014; Zhejiang Sci-Tech University, 2014; Zhejiang University of Finance & Economics, 2014; Zhejiang University of Media and Communications, 2014; Zhejiang University of Water Resources and Electric Power, 2014

Although China is known as the “Kingdom of Bicycles”, there was a significant decrease in bike users at the end of the 20th century (Government of Hangzhou, 2008). Hangzhou was no exception, with bicycle usage accounting for 60.8% of personal trips in 1997, but only 42.8% in 2000, and continuing a decline to 33.5% in 2007 (Shaheen, et al., 2011). Nevertheless, according to Weinert, while traditional bike usage is down, the existing bicycle infrastructure encourages the use of e-bikes (2008).

As part of the bicycle infrastructure, Hangzhou’s existing bicycle sharing system can shed light on the possibility of an electric bicycle program there. Formed to alleviate traffic congestion, improve air quality, and support public transportation, the bicycle system in Hangzhou is a solution for the first/last mile problem (Li, 2014; Mobiprize 2013). We define the first/last mile as the distance between the initial or final destination and public transportation. As mainland China’s first digital bicycle sharing system, Hangzhou Public Transportation Corporation (HPTC) officially launched its program on May 1, 2008 (Larsen, 2013; Shaheen, et al., 2011). It has continued to grow ever since. In May 2009, there were only 61 service points, and 2,800 shared bicycles in Hangzhou. At first, service stations were mainly located around popular areas for sightseeing. As more citizens and tourists began to rent bicycles, HPTC upgraded the rental system, simplified registration formalities, increased the number of service stations and prolonged the service hours (Chen, 2009). Today, Hangzhou has 60,000 public bicycles. Its goal is to have 175,000 public bicycles by 2020. Hangzhou plans to cover all residential areas, large shopping malls and supermarkets with service stations every hundred meters (Wang, 2012). Still, difficulties remain from an urban planning perspective; for instance, the bike sharing program cannot place stations on main roads because they will block the vision of drivers on the road, resulting in low visibility to potential users (P. Zhao, personal communication, October 31, 2014).

2.2.4.1 Hangzhou’s Subway System

Among the solutions for alleviating traffic congestion in Hangzhou, the subway system offers commuters speed, convenience, reliability, and large capacity for both passengers and luggage. Hangzhou subway Line 1 opened to the public on November 24, 2012, covering 48 km with 31 stations spread across the city through Xiaoshan, Linping and Xiasha districts (Hangzhou MTR, 2013). Three more stops in Line 1 will open in October, 2015. Line 1 passes through two railway stations, one bus station and a coach bus center, which is the biggest coach station in Zhejiang Province. Buses travel from the coach center to other stations in Hangzhou, as well as out of Hangzhou to different cities. The subway is a

convenient intermediate mode of transportation to high speed trains, railway and buses (Lin, 2012). Hangzhou plans to build a total of 10 subway lines by 2020. Line 2 is currently under construction; however on November 24, 2014, the southern part of Line 2 officially opened for operation (Chen, 2014). The northern part will open in 2017 (Lin, 2012).

The subway streamlined transportation in Hangzhou. Morning rush hour finished 20 minutes earlier and bus passengers decreased dramatically (Wu, 2013). In order to minimize the passengers' travel time, the system reduced the duration of time at each stop. The subway stops at each station for an average of 28 seconds.

Hangzhou MTR optimized the subway system by fostering speed and ease of use (Hangzhou MTR, 2013). Customer service centers provide transportation cards usable on nearly any form of public transportation in the city. The customer service center also answers general inquiries from passengers. The wide gate and lift accommodates wheelchairs, baby strollers, and baggage. In addition, passengers can monitor arrival times on display screens all along the subway platforms. However, terminal stations display screens only indicate the direction of the subway in Chinese. Thus, they may pose a challenge for foreigners as well as the visually impaired.

2.3 Requirements for Manual and Electric Bicycle Sharing

Bicycle sharing programs requires several elements of feasibility. In this section, we discuss the economic requirements, political involvement, environmental effects, health concerns, and social interest of manual and electric bicycle markets.

2.3.1 Economic Requirements and Political Support

In 2012, the systems in Beijing, Shanghai and Hangzhou exemplified three general bike sharing system designs, which Tang categorized as “Private Company-Led Model,” “Operator Company-Led, Government Aid Model,” and “Government-Led Model” respectively (Tang, 2011).

Many factors contributed to the success of Hangzhou's bike sharing system; however, analysts credit the government's role as critical (Jiang, 2011; Tang, 2011). The government implemented many modes of public transportation, ranging from the bus system to the subway with the intention of expediting travel while reducing cost (Weinert et al., 2008). In 2008, Hangzhou implemented its bicycle sharing service as part of the Public Transit Priority (Shaheen, et al., 2011). This priority, adopted in 2004, encourages the use of public transportation. With federal support, Hangzhou Public Transportation Co. had the funds to

expand and provide enough stations and bicycles to serve interested users. Recognized as a model bike sharing system, today Hangzhou earns revenue through selling and exporting its techniques to other cities (Li, 2014).

In particular, Hangzhou's bike system relied on investment from the government, discounted government loans, and revenue from advertisements. According to Peter Zhao, Vice President of Hangzhou Omnipay Co. Ltd, because the first hour of bike sharing is free; the majority of users return their bikes before this time (Peter Zhao, personal communication, October 31, 2014). This means the system receives minimal revenue through the actual sharing of bikes (Li, 2014; Shaheen, et al., 2011).

Peter Zhao stated that the e-bike sharing program would likewise be dependent on government funding (Peter Zhao, personal communication, October 31, 2014). The Chinese government is interested in improving its public transportation network. Based on studies done on the motorcycle industry (Sinocars, 2006; Sugiyama, 2003), Weinert and his team (2008) observed that government regulations typically favor only a few modes of transportation to optimize traffic flow and safety, as well as minimize environmental impact. Weinert also observed that some cities have banned motorcycles in order to promote electric bicycles.

China's electric bicycle production has grown rapidly in recent years, making this an advantageous time to invest in e-bikes (Guo, 2008). From 1996 to 2008, production increased about 154% on average, ranking first in the world, with Japan in second place. People consider buying electric bicycles because they are more affordable than cars. Figure 2.10 shows the increase in electric bicycle production in China from 1998 to 2004 (Li, 2014). The maroon colored bars represent e-bike production each year and the blue bars represent the cumulative total production since 1998 in units of ten thousand. The yellow line represents the percentage increase of e-bike production from year to year. In the six years represented, e-bike production has increased roughly 100 times. As of now, the production of e-bikes has skyrocketed ahead of the demand for them (Peter Zhao, personal communication, October 31, 2014).

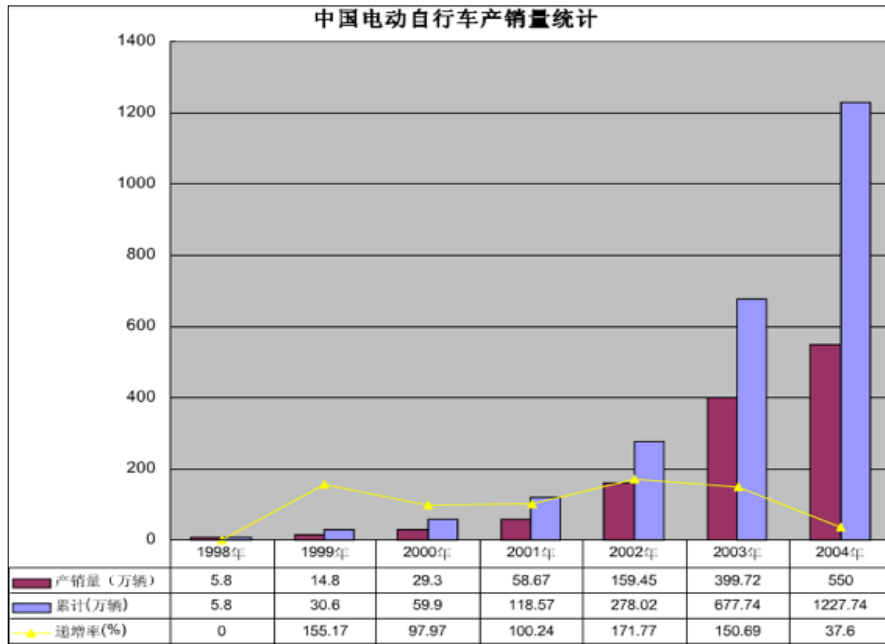


Figure 2.10: Development of Electric Bicycle Production Sales and Progressive Increase Rate between 1998 and 2004 in Hangzhou (Li, 2014)

In order to understand the implications of the e-bike sale market, we interviewed Christopher Cherry (2014), a Civil and Environmental Engineering professor who researched e-bike sharing at the University of Tennessee-Knoxville (UTK). He explained that because electric bicycles are so common in China, the public would not need to be “convince[d of] the value of an e-bike, most people know what they are.” He attributes the success of e-bike sales to the availability of huge manufacturing and maintenance infrastructure. Cherry suggests, although the markets for manual and electric bike sharing may overlap, the two services are not mutually exclusive. They offer different advantages based on the client’s need to travel. In Cherry’s view, there is enough economic incentive for an e-bike sharing system without taking away from the manual bike system.

2.3.2 Environmental Effects

Electric bicycle services can have both a positive and negative influence on the environment. Some cities have banned motorcycles in order to promote electric bicycles (Weinert et al., 2008). Competing bus and motorcycle services have higher greenhouse gas emissions than electric bicycles (Ji, Cherry, Han & Jordan, 2013). The electric bicycle partially solved urban noise and moped fuel-exhaust pollution. The development of the electric bicycle industry plays an important role in controlling oil prices, reducing environmental pollution, creating a convenient travel option and alleviating the urban traffic congestion (Guo, 2008).

E-bikes use only electricity and do not directly produce greenhouse gas or pollution. (Gribben, 1996). This means that e-bikes have the potential to lower these two harmful environmental factors if they replace gas powered vehicles. However, the electricity that powers the e-bikes will primarily be from coal burning power plants, meaning they will indirectly cause pollution. However, power plants can be more efficient than internal combustion engines, allowing electric powered vehicles to cause less greenhouse gas overall. If e-bikes replace walking and manual biking, then they will have a harmful effect on the environment.

The effect e-bikes has on the environment depends on the form of transportation users switch from. As Figure 2.11 shows, e-bikes use produce roughly ten times less carbon dioxide than cars per kilometer traveled (Cherry et al, 2009). E-bikes are also much more carbon dioxide efficient than buses, motorcycles, and electric scooters. E-bikes consume far less energy than these as well. E-bikes also cause far lower carbon monoxide than gas powered vehicles. The only forms of transportation that have a smaller environmental impact than e-bikes are walking and manual bikes.

| | Energy use (kWh/100 pax-km) | CO ₂ (g/pax-km) | SO ₂ (g/pax-km) | PM (g/pax-km) | CO (g/pax-km) | HC (g/pax-km) | NO _x (g/pax-km) | Pb ^c (mg/pax-km) |
|-----------------------------|--------------------------------|-------------------------------|-------------------------------|------------------|--------------------------|--------------------------|-------------------------------|--------------------------------|
| Car ^d | 47-140 | 102-306 | 0.23-0.69 | 0.09-0.28 | 3.4-10.1 | 0.57-1.67 | 0.44-1.32 | 18-53 |
| Bus | 8.7-26.2 | 24.2-96.8 | 0.01-0.04 | 0.04-0.14 | 0.08-0.32 ^e | 0.008-0.030 ^e | 0.14-0.54 ^e | 1-4 |
| Motorcycle | 21-42 | 64-128 | 0.04-0.08 | 0.20-0.40 | 6.3-12.5 ^e | 1.13-2.25 ^e | 0.08-0.15 ^e | 16-32 |
| Bicycle | 4.88 | 4.70 | 0.01 | 0.06 | Unkn | Unkn | Unkn | 0 |
| Bicycle style electric bike | 3.8-7.6 | 15.6-31.2 | 0.07-0.14 | 0.07-0.14 | 0.007-0.014 ^e | 0.027-0.053 ^e | 0.010-0.020 ^e | 145-290 |
| Scooter style electric bike | 4.9-9.9 | 20.2-40.5 | 0.09-0.17 | 0.10-0.19 | 0.009-0.017 ^e | 0.032-0.064 ^e | 0.014-0.027 ^e | 210-420 |

Figure 2.11: Energy Consumption by Vehicle (Cherry et al, 2009)

The e-bikes in Hangzhou would likely use a hybrid system that consists of charging at the station and charging while in use (Ji, 2011). Solar power could charge the bikes initially, then the city power could supplement when solar is inadequate. As the bikes are pedal assist, users could greatly increase the longevity of the battery if they utilized the power being produced by the user. This can greatly extend the distance an e-bike can travel by reducing the rate of depletion. It also cuts down on charging time since the battery will remain much less depleted after a trip.

Another cause for concern is the batteries that the e-bikes use. Peter Zhao, specified that the battery used in the e-bikes will be a 48V lithium ion battery (Peter Zhao, personal communication, October 31, 2014). Lithium batteries are the most commonly rechargeable battery, and found in a wide variety of electric devices (National Renewable Energy Laboratory). They are capable of contaminating water and soil if they leak or are not

disposed of properly. These types of batteries are also at risk when unqualified users tamper with them. This can cause the battery to burst or catch fire in a worst case scenario. That said, a proper facility can effectively dispose of lithium ion batteries, eliminating their environmental risk.

2.3.3 Health and Safety

Riding an electric bicycle offers the health benefits of riding a manual bicycle but with the support of an electric motor (Cherry, Worley, & Jordan, 2010). Like riding a manual bicycle, a cyclist pedals to operate an electric bicycle. A huge incentive to rent a manual bike is the physical exercise aspect (Webster & Cunningham 2013). But the main advantage of riding an electric bicycle is the physical support of electromechanical power, which helps the cyclist travel over long distances and steep elevations with less fatigue (Cherry, et al., 2010).

When riding electric bikes, cyclists should be aware of other vehicles on the road in order to mitigate safety risks. Although electric bikes are not as fast as motorcycles, cyclists on electric bikes sometimes share the road with cars and buses (GB17761, 1999; Weinert et al., 2008). However, e-bikes have slower speeds and can cause what is known as “erratic driving behavior,” both of which increase safety risks (Weinert et al., 2008). Weinert even suggests there is pressure to ban two-wheelers in order to mitigate risks while improving traffic circulation for automobiles.

2.3.4 Social Interest of an Electric Bicycle Market

By interviewing twenty-eight Hangzhou residents, Naess (2013) outlined the two primary rationales for why people travel to specific destinations. Residents travel to destinations that can best satisfy their needs, either by providing the best service or by requiring the least travel distance. Once residents decide a destination, they consider the mode of transportation that best accommodates their travel needs. The best mode of transportation has a favorable balance of time efficiency, mobility, low cost, enjoyment, safety, physical effort, and symbol of status.

Electric bicycles are favorable to Hangzhou citizens who travel long distances, enjoy natural scenery and prefer limited physical effort (Naess, 2013). Like motorized vehicles, electric bicycles enable commuters to travel longer distances than they could using manual transportation, such as manual bicycles or walking. Suburban residents rely on motorized vehicles like buses and cars to travel long distances into the city. But once they arrive, traffic congestion or lack of parking may limit their mobility. Needing to travel shorter distances

around the inner city, people rely on manual transportation like bicycling or walking for greater mobility. Similar to manual bicycles, electric bicycles offer the benefits of mobility in city traffic, and comfort in the bustling inner city environment. In comparison to buses and cars, clients can experience the scenery around them more vividly and save time by avoiding being stuck in traffic. Electric bicycles combine the benefits of manual bicycles in downtown and motorized vehicles from the suburban areas.

Depending on their occupation or demographic, people place different weights on various aspects of transportation defined by Naess as time saving, expanding the radius of action, money saving, limiting physical efforts, safety, as well as demonstrating wealth and status (Naess, 2013). In terms of minimizing travel cost, manual bikes are preferable to buses and taxis. E-bike users are often professionals, students, couriers, food delivery men, housewives or elders (Shi, 2013). Each of these occupations has different reasons for using e-bikes as shown in Table 2.5. While white collar workers use e-bikes to ensure prompt arrival at work, blue collar workers like delivery men rely on e-bikes to conduct their business. Likewise, housewives and students ride e-bikes to travel between school buildings or markets in their daily routines. On the other hand, the elderly use e-bikes as an alternative to regular bicycles due to physical limitations.

Table 2.5: The Reason for Using E-Bikes for Various Occupations (Shi, 2013)

| Occupation | Reason for E-Bike Usage |
|---------------------------------|---|
| Professionals | Want to save on spending, and not be late to work |
| Students | Convenient for getting around large campuses and getting to class |
| Couriers & Food Delivery men | Want to save manpower, cost, and increase work efficiency |
| Housewives | Pick children up from school, buy food from market. An electric bicycle can fit three people. |
| Elderly | Transportation is a difficult choice, bicycles are convenient but still needs manpower, and cars are costly and troublesome to park |

The occupations mentioned in Table 2.5 also have different criteria when selecting the model of electric bicycles. Professionals consider implications of social status and choose electric bikes based on stylish appearance (Shi, 2013). Naess writes that people may not choose the most economic mode of transportation in order to demonstrate wealth and status (2013). Students also choose electric bikes based on appearance and convenience (Shi, 2013). Couriers and food deliverymen often have multiple clients and rarely travel long distances. Load capacity and practical design is more important to couriers and food deliverymen because they need to carry goods. Safety is the most important feature to housewives and the elderly.

2.3.5 User Interface

According to Cherry (2014), human managers play a more significant management role than sophisticated software in China. Thus digital user interfaces are often simple in design, requiring minimal software interaction. Hangzhou Omnipay Co., Ltd. develops the bike sharing equipment and software as well as manages the process of bike rentals. As shown in Figure 2.12a, common service stations have a row of easy access service totems posted by an attendant booth (C. Huang, personal communication, November 4, 2014). Easy access service totems (Figure 2.12b) manage daily bicycle rentals. To rent a bike, a customer taps their transportation card to the service totem. Once the software recognizes the credit value of 200RMB or over, the locking bolt will withdraw to release the bicycle. To return the bike, the customer needs to fit the lock onboard the bike to a slot on the side of the service totem. Once fitted, the customer taps their card to pay and lock the bike. If all totems are occupied, a customer can return the bike to an attendant. At the attendant booth, the customer can also check the balance on the transportation card using the Omnipay kiosk (Figure 2.12c). Reflecting Omnipay's green initiatives, the user friendly interface promotes environmental initiatives including green transportation and recycling (Larsen, 2013; Kaiser, 2012; Mobiprize, 2013).



Figure 2.12: (a) Common Service Station, (b) Easy Access Service Totems, (c) Omnipay Kiosk (Mobiprize, 2013)

A common station for subway, buses and bike sharing, the East Railway Station serves as a center for the transportation network (C. Huang, personal communication, November 4, 2014). To compensate for the higher traffic volume of commuters from this station, it houses a bigger than usual bike sharing station. Users access bikes in a gated parking lot that is supervised by an attendant. The gates are similar to the service totems, equipped with a locking port and card detection software. To rent a bike from this gated lot, a customer needs to enter the gated lot and choose a bike. Then the customer pushes the selected bike to the entrance and matches the locking apparatus with the locking port at the gate. Finally, the customer taps the transportation card at the exit gate to register and release the rented bike. To return the bike, the customer simply pushes the bike through the entrance gates and taps the transportation card on the entrance gate.

The transportation card is a key component of the transportation network. According to transportation clerks, clients can purchase a card for 20 RMB and deposit an amount of their choosing; however, a credit value of 200 RMB is required to rent a bike (Chen, 2009). According to Omnipay, the cards store monetary credit into two accounts, a transit account and a miscellaneous account (P. Zhao, personal communication, October 31, 2014). Credit in the transit account can be used to pay for the subway, buses, taxis, bike sharing, and even water transit. Credit in the miscellaneous account can be used for purchases at participating

establishments. At every bicycle sharing station, customers can use Omnipay's kiosks to check the balance on their card or add credit using prepaid gift cards.

Clients of Hangzhou's current bike sharing system can ride the manual bike for an hour free of charge after registration (Kaiser, 2012). After an hour, clients can continue riding by paying 1RMB for 1-2 hours, 2RMB for 2-3 hours and 3RMB per hour after 3 hours. To encourage transfers between transportation services, bike sharing stations are located at transit stations like bus stops (Kaiser, 2012; Shaheen, et al., 2011). The system rewards a free hour on a bicycle to clients who use the same card to transfer between buses and bicycles (Larsen, 2013; Kaiser, 2012).

2.3.6 Potential Technology

A service station that automatically locks and charges returned e-bikes would ensure both security and convenience (C. Cherry, personal communication, October 11, 2014). However, such a system requires hiring technicians or developing more sophisticated software. Omnipay is designing an e-bike station that is similar to Cherry's concept (P. Zhao, personal communication, October 31, 2014). A locking key is attached to the front of the e-bike and a receiving slot is provided by the station. To return the e-bike, the user fits the locking key into the slot by pushing the e-bike into the station.

2.4 Summary

While people in China use private electric bicycles in many cities in China today, an e-bike sharing system does not currently exist. Many cities around the world are currently implementing their own e-bike sharing systems. We have described the qualities of manual bike sharing systems; however no currently published research explains the elements that would make an e-bike sharing system feasible on a scale as large as Hangzhou. Nevertheless the qualities of existing e-bike and manual bike sharing systems offer references to determine the feasibility of implementing an e-bike sharing system in Hangzhou.

Chapter 3: Methodology

This project aimed to determine the feasibility of a successful electric bicycle sharing system in the Xiasha District of Hangzhou. In order to attain this goal, we determined demand in Xiasha for an e-bike sharing system, identified the economic and environmental benefits and costs of implementing an e-bike system in Xiasha, and determined if Xiasha has the appropriate infrastructure for supporting an e-bike sharing system. To achieve our objectives, we used methods that include interviews, surveys, direct participation, observations, research, and focus groups.

3.1 Determine the Demand in Xiasha

In order to identify if demand in the Xiasha District is sufficient for an e-bike sharing system, we conducted surveys and focus groups targeted at students in the Xiasha Higher Learning Garden area, home to approximately 190,000 students and fourteen universities. We structured the surveys to provide us with answers to the modes of transportation that students currently use as well as their interest in e-bikes.

3.1.1 Surveys

To understand the student interest in electric bicycles, we surveyed a sample population of 680 students from five universities located across the Xiasha Higher Learning Garden (please refer to Appendix A for a complete Chinese translation of the survey and Appendix B for an English translation). The purpose of our survey was to identify students' perception and demand for e-bike sharing.

Measuring the current students' perception and demand for electric bicycles helped us assess current use and set the baseline for analysis of e-bike sharing potential. Through the survey, we collected data about how often people used different modes of transportation. We listed common modes of transportation based on literature review and direct observation. These included:

- Subway
- Public Bus
- Private Van Service
- Taxi
- Public Shared Car
- Private Electric Scooter
- Private Gas Scooter
- Public Shared Bicycle
- Private Bicycle
- Private Car
- Walking

We selected common reasons to act as *choice factors* that students may consider when choosing transportation. Our team asked students to select up to four items in both the “Reasons to Choose” and “Reasons to Avoid” categories, represented in Figure 3.1. We used this question in order to understand what characteristics students look for in a mode of transportation. Through this knowledge, we projected whether or not e-bike sharing might characterize the most common reasons and therefore interest potential users. This also provided information to Omnipay so that they can cater e-bikes to a wider audience.

2. What are the biggest factors that affect your choice of transportation? Select up to four in each category.

2.1 Reasons to Choose

- | | |
|---|---|
| <input type="checkbox"/> Price | <input type="checkbox"/> Work Related |
| <input type="checkbox"/> Convenience | <input type="checkbox"/> Little Physical Effort |
| <input type="checkbox"/> Carrying Items | <input type="checkbox"/> Group Travel |
| <input type="checkbox"/> Safety | <input type="checkbox"/> Good for Environment |
| <input type="checkbox"/> Travel Speed | |
| <input type="checkbox"/> Style | |

2.2 Reasons to Avoid

- | | |
|---|---|
| <input type="checkbox"/> Traffic | <input type="checkbox"/> Too Slow |
| <input type="checkbox"/> Expensive | <input type="checkbox"/> Needs Physical Effort |
| <input type="checkbox"/> Technical Difficulties | <input type="checkbox"/> Lack of Personal Space |
| <input type="checkbox"/> Cannot Carry Items | <input type="checkbox"/> Weather |
| <input type="checkbox"/> No Parking | <input type="checkbox"/> Bad for Environment |
| <input type="checkbox"/> Often Not Safe | |

Figure 3.1: Reasons to Choose or Avoid Modes of Transportation

Twelve of the *choice factors* had counterparts, creating 6 pairs that we considered as one *choice factor* for data analysis. For example, “Little Physical Effort” and “Needs Physical Effort” fall under the factor of “Physical Effort.” Table 3.1 depicts all of the fifteen factors that the survey considered. Using the data, we ranked the importance of each *choice factor* according to the number of responses it received. If a student selected both of the counterparts for a particular *choice factor*, we counted this as one response. For instance, if a student selected both “Good for the Environment” and “Bad for the Environment,” then we counted one response for “Environment.”

Table 3.1: Factors indicated by Reasons to Choose and Reasons to Avoid

| Reasons to Choose | Reasons to Avoid | Factor |
|------------------------|------------------------|------------------------|
| Price | Expensive | Price |
| Carrying Items | Cannot Carry Items | Carrying Items |
| Safety | Often Not Safe | Safety |
| Travel Speed | Too Slow | Travel Speed |
| Little Physical Effort | Needs Physical Effort | Little Physical Effort |
| Good for Environment | Bad for Environment | Good for Environment |
| Convenience | - | Convenience |
| Style | - | Style |
| Work Related | - | Work Related |
| Group Travel | - | Group Travel |
| - | Traffic | Traffic |
| - | Technical Difficulties | Technical Difficulties |
| - | No Parking | No Parking |
| - | Lack of Personal Space | Lack of Personal Space |
| - | Weather | Weather |

By analyzing which *choice factors* students marked most frequently, we generalized the main factors that affect students' decisions about transportation. We did not specify a mode of transportation in order to gather general reasons about the choice of transportation. Nevertheless, students may have been considering certain modes when indicating these reasons. Thus the reasons they indicated may not be specifically about their decision process, but rather pertain to a specific mode.

To understand the public perception of e-bikes, we asked students to rate various aspects associated with e-bikes from 1 (least) to 5 (most). These numerical ratings identified the importance of environmental friendliness to the student population. In order to identify the aspects perceived to be strengths or weaknesses, we prompted the students to rate electric bikes in safety, convenience, and travel speed. Furthermore, we asked directly if the student would be interested in e-bike sharing to gather definitive statistics about student interest. If the student indicated low interest ("Not sure" or "Definitely not"), the survey asked him/her to specify their concerns. If the student indicated higher interest ("I would probably use it" or "I would definitely use it"), they did not need to indicate concerns. However, some students who showed higher interest also specified concerns. By analyzing how often students selected each option, we determined the main public concerns about e-bike sharing. Generalizing these aspects, we identified the aspects Hangzhou Omnipay Co., Ltd. should focus on in order to implement a successful e-bike sharing program. Some students found the

rating system confusing. Some students circled the words at the end of the scale rather than the numbers in between. In these circumstances, we represented their responses as 1 or 5, depending on the word they circled. For example, if a student answered question 4.2 shown in Figure 3.2 regarding e-bike safety by indicating “Dangerous,” we considered this response a “1” on the scale. Likewise, if the respondent selected “Very Safe,” we listed the response as a “5.”

4. On a scale of 1 to 5, please circle your rating for the following aspects of electric bicycles.

| | | | | | | | |
|---|----------------|---|---|---|---|---|-----------------|
| 4.1 Is environmental friendliness important to you? | Not Important | 1 | 2 | 3 | 4 | 5 | Very Important |
| 4.2 Safety | Dangerous | 1 | 2 | 3 | 4 | 5 | Very Safe |
| 4.3 Convenience | Not Convenient | 1 | 2 | 3 | 4 | 5 | Very Convenient |
| 4.4 Travel Speed | Slow | 1 | 2 | 3 | 4 | 5 | Fast |

4.5 Would you be interested in an e-bike sharing?

- Definitely not
 Probably not
 Not sure
 I would probably use it
 I would definitely use it

4.6 If no interest in E-bike sharing, why? (You answered definitely not, probably not, not sure above.) Check all that apply.

- Not Reliable Expensive
 Not Convenient Not Safe
 Not Clean Noisy
 Low Quality Other _____
 No Insurance

Figure 3.2: The Rating Questions

To ensure that our data reflected the student population, we determined the demographics (questions 6, 7, and 8 as shown in Figure 3.3). We limited our analysis to responses from undergraduate and graduate students, eliminating surveys that answered “Faculty” or “Other” as their occupation. We analyzed these responses under the assumption that undergraduate and graduate students share similar needs in regards to transportation and are similar in age. Because the scope of our study focused on universities, we asked students to indicate their residence: “On Campus,” “Off Campus” or “Other.” Although students live in different campus buildings with varying access to transportation, we assumed similar needs for transportation. Students who live off campus and other are not under the same generalization. We analyzed the ratio of students who live on campus to off campus and other to quantify the need to travel within campus versus the need to commute into campus. We asked students to list their genders to see if males or females showed different trends in the data.

6. Occupation

- Undergraduate Student
- Graduate Student
- Faculty
- Other _____

8. Residence

- On Campus
- Off Campus
- Other _____

9. Gender

- Male
- Female

Figure 3.5: Demographic Questions

In order to understand the general perception of transportation in Xiasha, we conducted 680 surveys at five universities. We chose five universities to represent more than a third of the 14 schools in the Xiasha Higher Learning Garden. Our team conducted 680 surveys to get a sample size for the 95 percent confidence level. The student population for the district is approximately 190,000. To receive a sample with +/- 3% error we needed between 678 and 682 survey responses for a population with an 80/20 split. An 80/20 split means that most of the respondents share a certain characteristic. We selected universities located near our host university, Hangzhou Dianzi University (HDU), as well as others spread across the district at varying distances from subway stations (existing or planned for completion in October, 2015). We included subway stations planned for construction because these stations may be active when a new e-bike system is implemented. The five surveyed universities included three near current subway stations: (1) Hangzhou Dianzi University, (2) Zhejiang Sci-Tech University, (3) Hangzhou Vocational and Technological College; and two near the planned future subway stations: (4) Zhejiang University of Finance and Economics, (5) Hangzhou Normal University. Figure 3.4 shows the location of the five schools that we surveyed and their spread across the district. The red M's represent current metro stations and blue M's represent future stations which are under construction.

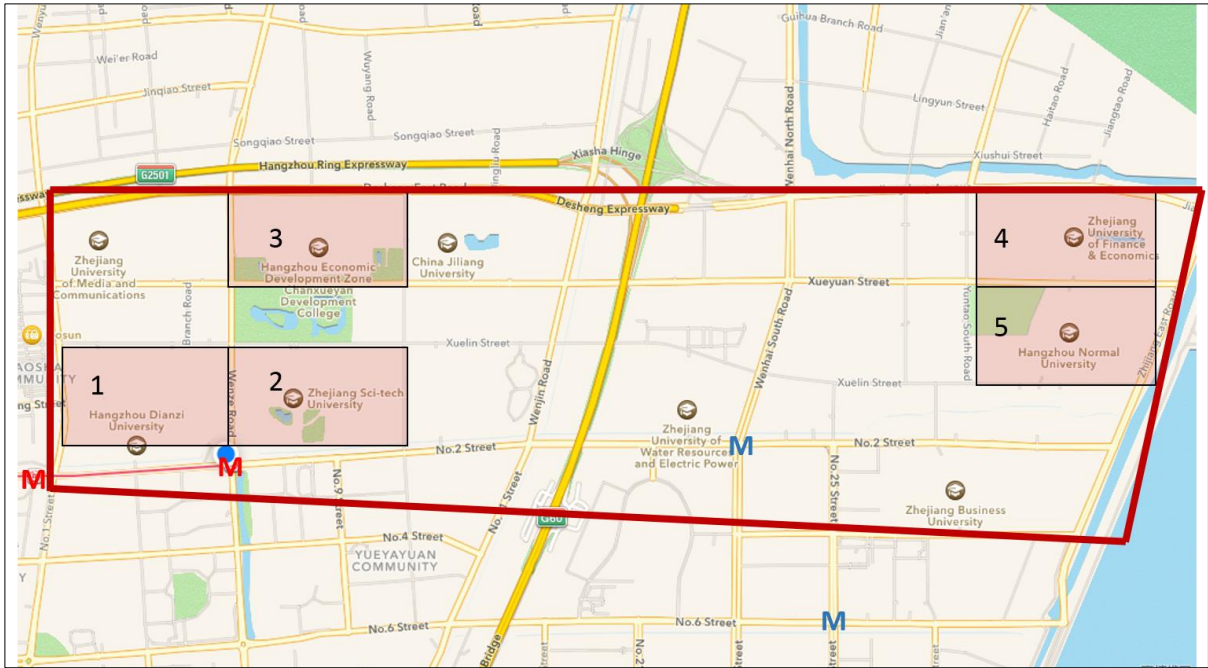


Figure 3.6: The Locations of the Five Surveyed Universities (Apple Inc., 2014)

We focused surveys on the Xiasha District due to time constraints, and because Omnipay desired a campus area study. In order to reach the desired number of 680 surveys, we considered the population size of the schools. A 1:160 ratio allowed us to sample a proportionate amount of students at each university. Table 3.2 shows the student population and number of surveys conducted at each of the five universities. The sum of the surveys is more than 680, allowing us to eliminate incomplete surveys. We also limited the study to five universities because it took time to find a good location at each university to survey students. Also, because one potential university asked us to leave before we completed surveying, we created a method that would give us 680 surveys even if nine of the fourteen universities in the district asked us to leave.

Table 3.2: School Population and Suggested Survey Count

| School | Population | Surveys |
|---|------------|---------|
| Hangzhou Dianzi University (HDU) | 28,000 | 175 |
| Zhejiang Sci- Tech University (ZSTU) | 27,000 | 169 |
| Hangzhou Normal University (HNU) | 18,834 | 117 |
| Zhejiang University of Finance and Economic (ZUFE) | 24,000 | 150 |
| Hangzhou Vocational and Technological College (HVTC) | 10,000 | 75* |
| * We decided to take a minimum of 75 surveys at this university, even though the 1:160 ratio called for 63 surveys. This allowed us to have extra data to replace incomplete surveys from other universities if needed. | | |

In order to overcome the language barrier and conduct surveys efficiently, our bilingual team member translated the survey into Chinese. This allowed the non-native speakers in the group to proctor the completion of the surveys. Most students completed the survey without raising any questions. When students did have questions, the Chinese team member answered them in Chinese. Another team member with limited language skills also helped in this regard. When we did offer some explanation, we may have affected the students' responses. Most of the questions asked students to check the responses that applied. We included responses based on literature research, sponsor suggestions, or direct observation.

To give a professional impression to passers-by, we stayed within visual proximity of each other as an indication that we were an official research team. We used English and our foreign appearance to our advantage to attract respondents. Nevertheless, the language barrier limited our interaction with the students and, we could not always explain how to adequately complete the questions.

Overall, we administered surveys on four separate days between November 19 and December 2, 2014, during the time interval of 10:00 to 18:00. We chose this interval because we found it more efficient to survey students outside in daylight. On certain days, we surveyed students at multiple schools in order to allow our group time to input and analyze the data. We selected locations on each of the campuses where there appeared to be high student traffic. This allowed us to collect the needed surveys in under two hours at each university. Using convenience sampling, we achieved our calculated sample size of 680 total survey responses, representing the student population in the Xiasha Higher Learning Garden.

3.1.2 Focus Group

We created a focus group of HDU students to determine their willingness and reservations about e-bike sharing. We chose to conduct our focus group with students because they are the primary demographic that Omnipay is concerned with. We had connected with some of these students prior to our arrival in Hangzhou, and the others were friends of the students who were partnered with the cohort of twelve WPI students conducting research at HDU. Questions asked probed their primary concerns such as how much they were willing to spend on a deposit. We posed questions to the group and allowed participants to respond at will. Our team encouraged quiet participants to speak freely when necessary. Our Mandarin speaker needed to translate several questions to the group, but

because of the demographic (university students), the students all had enough knowledge of English to respond in English. There were a total of ten participants in the focus group.

3.2 Identify the Environmental Costs and Benefits

We determined the economic and environmental repercussions of implementing this system. To do this, we used our survey and focus groups with students to predict how an e-bike sharing system would affect these aspects of the Xiasha district. We considered the questions: How does an e-bike sharing system benefit the people? What do the users want from the system? How might the implementation of a new mode of transportation affect the people?

3.2.1 Survey

In our survey, we asked questions to evaluate how well the students understand the benefits and disadvantages of e-bikes, including the environmental influence, transit safety and convenience (see Appendix A [Chinese] or B [English] for complete survey).

This feedback helped us understand the student perception of electric bicycles. The survey also asked students' method of transportation in daily, weekly, and monthly intervals. In addition, we quantified the baseline travel cost acceptable to the customer. Omnipay suggested that students currently try to return bikes in under an hour to avoid the hourly charge. We used our survey to confirm this speculation and also determine the highest hourly charge students would be willing to pay for e-bike sharing. The proportion of the responses helped us quantify students' willingness to pay. Omnipay speculated that the majority would answer, "None. I only use the free hour" and was especially interested in this question. We prompted students to select the highest hourly charge they would accept for e-bike sharing, ranging from "1 RMB" to "5+ RMB". Through the survey statistics, we gained a better understanding of the needs of the customer.

In order to help Omnipay achieve its goal of greener transportation, e-bikes should complement other public transportation, including subway, bus and manual bike. We asked students to identify the types of transportation they use when they transfer to/from shared bicycles (Figure 3.5). In addition, the survey asked students to rank the importance of environmental friendliness to them. This information, combined with the data collected from the *choice factor* of "Good for Environment" and "Bad for Environment" allowed us to quantify the importance of the environment to students. Also, through analysis of question 1 "How often do you use these modes of transportation?" we determined which mode of

transportation e-bike sharing would displace the most. Using this information, we predicted whether a public e-bike sharing system would have a positive or negative influence on the environment.

3. In the last 7 days, did you use a shared bicycle in conjunction with another form of transportation? Check all that apply.

- | | | |
|---------------------------------|--------------------------------------|--|
| <input type="checkbox"/> Subway | <input type="checkbox"/> Taxi | <input type="checkbox"/> Walking |
| <input type="checkbox"/> Bus | <input type="checkbox"/> Private Car | <input type="checkbox"/> None of the Above |

4. On a scale of 1 to 5, please circle your rating for the following aspects of electric bicycles.

4.1 Is environmental friendliness important to you? Not Important | 1 2 3 4 5 | Very Important

Figure 3.9: Transfers with Shared Bicycles and Importance of Environmental Friendliness

3.2.2 Focus Groups

We used focus groups to determine which modes of transportation would be displaced, in order to predict the effects the system would have on the environment. We asked questions specifically pertaining to which transportation systems they used the most, and if they would be willing to use e-bikes instead. This gave us an accurate idea if implementing the system would have an overall positive or negative effect on the environment. For example, if many car drivers switched to e-bikes then the effect would be positive.

3.3 Determine if Hangzhou has the appropriate infrastructure

In order to determine if the Xiasha District had the appropriate infrastructure for supporting an e-bike sharing system we used the methods of literature-based research, interviews, direct observation, participation, and mapping. We defined appropriate infrastructure in terms of accessible transportation connections, electrical supply, and bike lanes. We chose to define our objective in these terms in order to set a fundamental framework for analyzing the infrastructural resources available to Xiasha. Determining this information allowed us to analyze transportation infrastructure in terms of e-bike sharing needs.

3.3.1 Survey

Using the same survey as previously discussed, we determined what types of transportation people used most often (Question 1, How often do you use these modes of transportation?). In addition to this information, we asked questions about what types of

transportation students used in conjunction with the current public bicycle sharing system (Question 3, In the last 7 days, did you use a shared bicycle in conjunction with another form of transportation?). By analyzing this data, we made proposals for which types of public transportation e-bike stations should be located near in order to best complement the current transit system and encourage use. If students responded “None of the Above” to Question 3, then we checked to see if they had also selected “I don’t rent bikes” for Question 7 to see if that was the reason.

To supplement the location predictions, we also asked students to list their residence information: On Campus, Off Campus, or Other; we did not provide space to elaborate what “other” meant. We chose to limit the responses to checked boxes due to time constraints and difficulty translating handwritten answers. Even with these limitations, knowing whether students’ residences were on campus or not could help determine e-bike station locations convenient for the student population of Xiasha. If most students responded that they lived “On Campus” then stations near the perimeter of campus would provide access to the rest of the city. If “Off Campus” or “Other” represented a large portion of the sample population, then a more detailed survey about the neighborhoods could provide answers to the best location for e-bike stations.

3.3.2 Direct Participation and Observation

Through direct observation and participation, we researched the extent of and ease of use of the current transportation infrastructure in Hangzhou. We used the different forms of public transportation, including the subway, taxis, buses, and bikes to understand the fluidity and integration of Hangzhou’s transportation system. Each team member purchased the transportation card to allow for switching between subway, bus, taxi, and bike networks with the convenience of one payment method. Users can only access public bicycles with a transportation card, while they can use other forms of transportation with cash or a ticket. Direct participation allowed us to experience firsthand how commuters and Hangzhou residents can transition between different forms of transportation to get around the city, including travel between the different districts. Figure 3.6 shows the location of the Xiasha District within the scope of Hangzhou, to the northeast of the downtown area.

In addition to assessing existing current transportation infrastructure, we determined if the Xiasha District has the capability to support an e-bike sharing station. Electrical power is one of the key differences between a manual bike sharing system and an electric bike sharing system. However, due to limited access to resources and time, the following section of our methodology mostly serves as a basis for future research.



Figure 3.10: The Xiasha District (Baidu, 2014)

3.3.3 Mapping

We developed a physical map of the existing bike sharing stations in Xiasha to help outline the existing infrastructure. A current map did not exist in part because bike share program often moves stations (Shaheen, Zhang, Martin & Guzman, 2011; P. Zhao, Personal Communication, October 31, 2014). The free phone application iCity China, developed by Zeonic (Shanghai) Information Technology Co., Ltd. iCity China displays the location of bike sharing and bus stations in the district of Xiasha. Using the version updated on November 14, 2014, we located the bike sharing stations in the application and marked them in black on a published map. For mapping purposes, we interpreted the bus and subway routes, seen in Figure 3.7, as the outline of the transportation network. Green dots represent bus stations and green lines indicate bus routes as printed on the map. Purple symbols

represent subway stations and a dotted, thick green line depicts the subway route. We did not include taxis in this analysis because they do not have established rally stations. To quantify the scale of the current bike sharing network in Xiasha, we counted the total number of bike, bus and subway stations within the boundaries of Xiasha, as denoted by a thick dotted purple line printed on the map. The scale of the bike sharing network may shed light on the accessibility of the network. We calculated a size ratio representing the scale of the bike sharing system in comparison to the public bus service and the subway. To quantify how extensively bike sharing is integrated with bus and subway system, we counted the number of bicycle stations along each bus and subway route. For this analysis, we only counted bike sharing stations located immediately next to the bus route. We did not count bike sharing stations that were located on other streets or within facility areas (represented in yellow on the published map). We included the future subway extension as part of the subway route because in the long term, the extended subway and e-bike sharing may both be active. Line 1, which connects Xiasha with the main transportation center (East Railway Station) and downtown, will have three additional stops in the Xiasha District by October 2015. Because the subway route is more limited in scale compared to the bus network, we counted bike sharing stations within the proximity of the subway stations (about 1 cm on the map).

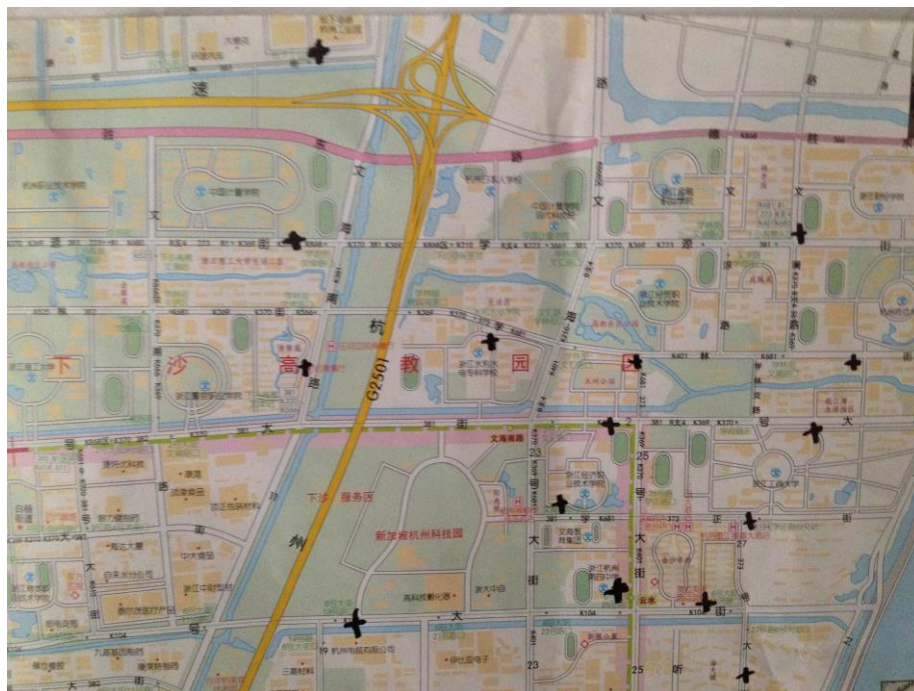


Figure 3.12: Marked Map

While we designed the above methodology to achieve this project’s objectives, we note limitations. The iCity China software had an update on November 14, 2014 (only one week prior to our constructing the public transportation map), yet we discovered through a

verification process of comparing the mapped location to the actual physical location that accuracy was limited. Nonetheless, the software located bike stations more accurately than we could by navigation on foot. Even if the software was fully accurate, plotting the stations by hand was still subject to human precision and error. Although we tried to pinpoint exact the locations of bike stations on the map, we approximated the actual placement on the map. In addition, the system sometimes relocates bike stations and infrastructure changes with time (Shaheen, Zhang, Martin & Guzman, 2011; P. Zhao, Personal Communication, October 31, 2014). Accounting for these limitations, we produced a physical map that was sufficiently accurate to mark the locations of all bike sharing sites as of November 2014. Despite the gradual changes the transportation network may undergo, our map displays the information necessary to analyze the scale and functionality of the current network.

3.3.4 Interviews

To further our investigation of the available power supply we determined whether the capacity of the transformer in the green sheds at each manual bike sharing station would support the charging requirements for an e-bike station. Due to the limitations of our observations (we were not able to gain access to one of the transformers) we chose to address our questions through an interview with Peter Zhao and Chao Huang of Omnipay and Ying Gaofeng of ShareGreen Company. Omnipay introduced Mr. Ying to us as their connection to the electric bike manufacturer who is involved with the project. GreenShare Company is a high-tech company that was founded in 2012. The company focuses on developing intelligent public transportation systems to provide a more convenient and efficient service to people. The company currently has two main products. One is LoPa Parking position lock. LoPa is an app for smartphones. People can use the app to control the Parking Position Lock through the Bluetooth on their smartphones, and they also can share their Parking Position status information online. When Parking Position is empty, another driver can find and book the position easily through the internet. This app solves the parking problem in downtown Hangzhou very effectively.

Another product is an intelligent bike sharing system. All information, like the status of bikes and position of bike stations will be updated online, making information necessary for participating in the bike sharing system readily accessible and efficient. The future goal of the company is to provide an intelligent system for public transportation by compiling and conveniently organizing all information about public transportation through the Internet and smartphones.

In anticipation of the interview with Mr. Ying, we prepared three questions:

1. How much time and power is required to charge the e-bike battery?
2. What demographic represents your highest sales?
3. What is the process required for getting the e-bike repaired?

The first and third questions led to insights regarding the infrastructural feasibility of an e-bike sharing system. With knowledge of the power requirements for the e-bike battery, we could determine whether or not the current bike sharing stations had the electrical capacity to support the charging of e-bikes. Maintenance of the e-bikes represents another infrastructural concern, as it determines the availability of the bikes. As mentioned in section 2.1.3 on Copenhagen's bike sharing system, availability is one of the biggest factors of a vehicle sharing scheme. Both charging and maintenance influence the operational time of e-bikes, and thus the availability of e-bikes to users, making these questions relevant to our study.

The intention of the second question was to see if the student demographic already had a high level of familiarity with and desire for e-bikes. If the young adult age group (~18-25) represented the highest contributor to e-bike sales, then our focus on the Xiasha Higher Learning Garden would be a viable target group for e-bike sharing.

In the course of the interview, Mr. Ying also provided other information on e-bike speed and cost relevant to user safety and payment respectively. Please refer to Appendix C for a full list of questions from the interview with Ying Gaofeng.

3.4 Summary

To achieve the objectives of this project, we researched Hangzhou's existing transportation infrastructure and the services available through direct observations, participation, research, and mapping. By conducting surveys and focus groups, we identified the potential effects of, as well as student interest in, electric bicycles. Through a combination of these methods, we collected the necessary data for evaluating the feasibility of an electric bicycle sharing system in Hangzhou.

Chapter 4: Findings and Analysis

The goal of our project was to determine the feasibility of an electric bicycle (e-bike) sharing system in the Xiasha District of Hangzhou. We organized this section of our report by the three objectives we used to accomplish our goal. Based on the responses from our survey and a focus group, the findings showed trends between the needs of the potential customer base and aspects of feasibility. Direct participation, observation, interviews, and mapping revealed the potential of Hangzhou's current transportation infrastructure to support an e-bike sharing system. Student demand, environmental costs and benefits, and capable infrastructure provide the framework for our analysis.

4.1 Demand in Xiasha

In this section, we discuss user interest in and concerns about e-bike sharing in the Xiasha District. Our findings reflect the significance of safety, price, and social implications to students. We used a survey of 680 students in the Xiasha Higher Learning Garden and a focus group consisting of ten students from Hangzhou Dianzi University in order to gauge student perceptions. If our survey sample correctly represents Xiasha Higher Learning Garden with 95% (+/- 3%) confidence, then the 680 students we surveyed represents 190,000 students. We chose five of the district's fourteen universities for our sample population due to time constraints. We provide user population estimates based on techniques described in "Determining sample size for research activities" by Krejcie and Morgan (1970).

4.1.1 Student Interest

In order to determine student interest in e-bike sharing, we used our survey to understand overall willingness of students in Xiasha to use the system. Our survey found that the students of Xiasha were interested in an e-bike sharing program. As seen in Figure 4.1, 43% of survey takers responded “I would probably use it” and 8% responded “I would definitely use it”. This means that just over half of the population will likely be the user base; a good starting point for the system. Only 29% of the population was uninterested in the system, with 25% and 4% answering “I would probably not use it” and “I would definitely not use it” respectively.

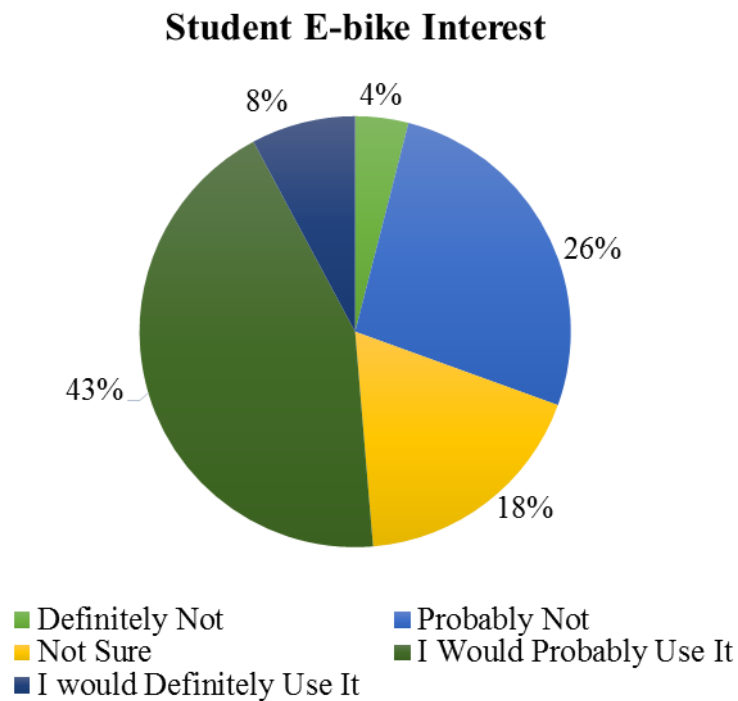


Figure 4.2: Student Interest in Xiasha Higher Learning Garden

4.1.2 Student E-Bike Concerns

Hangzhou Omnipay Co., Ltd. may be able to sway more potential users into using the system by addressing concerns that people have with e-bikes, particularly the survey responders who answered “Not sure”. In our survey, we asked a multiple choice question to determine the factors that dissuade people from using e-bikes. We did not limit the number of deterrents that students could indicate. Figure 4.2 shows the various choice factors in order of how many responses each received. The most significant deterrents from using e-bikes were by far the choices “Not Safe” and “No Insurance”; however, over 100 students indicated that reliability and convenience concerned them as well.

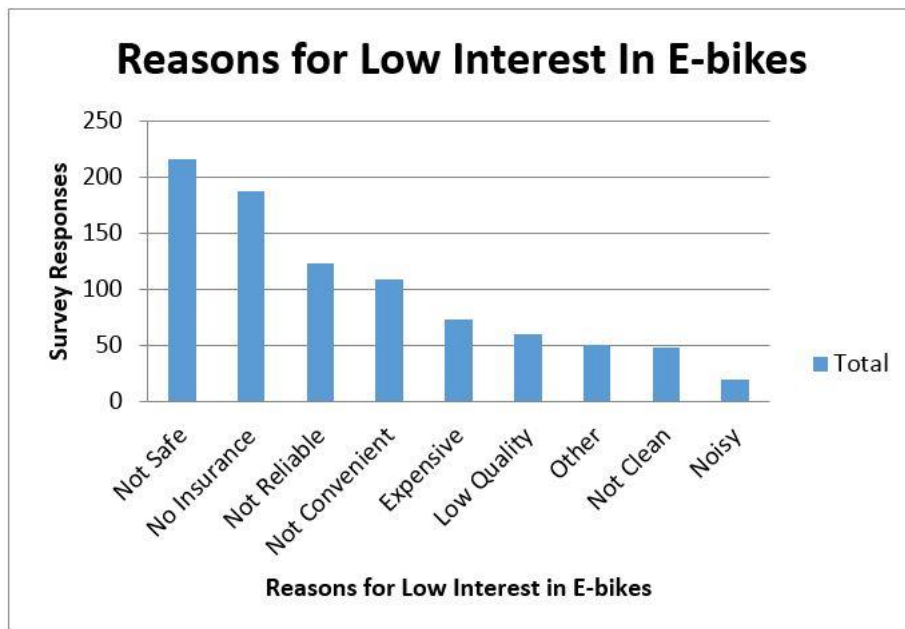


Figure 4.3: Reasons for Low Interest in E-bikes

4.1.3 Safety

Since e-bike safety was the greatest concern for students, we determined the student population's perception of e-bike safety on a scale of 1 (Dangerous) to 5 (Very Safe). As is seen in Figure 4.3, 42% of respondents answered that e-bikes were a 4 or 5 in terms of safety, which is a sizable percentage. However, 23% felt that e-bikes were dangerous (1 or 2). Thus, we found that safety deters some students from e-bike sharing. In addition, we determined that travel safety was a deciding factor in choosing a mode of transportation. Consequently, Omnipay should consider e-bike safety when implementing an e-bike sharing system.

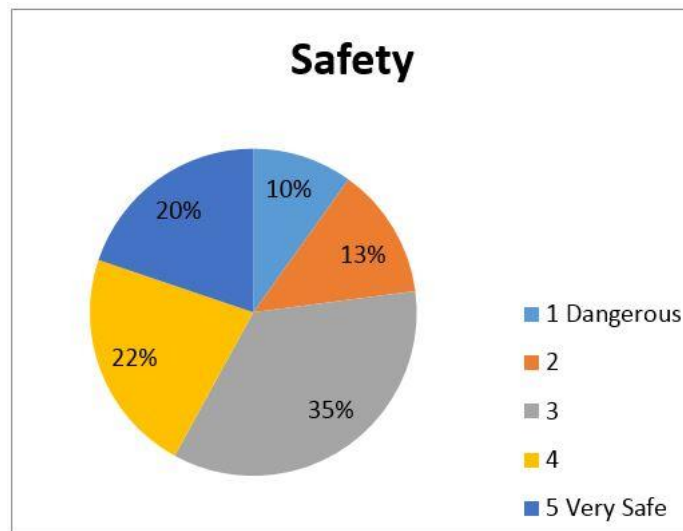


Figure 4.4: Rating of E-bike Safety

The focus group revealed the characteristics of safety that matter most to students were vehicle collision, braking time, and bike stability. E-bikes could intimidate users who do not feel comfortable riding at high speeds on less than ideal road conditions. However, designated bike lanes provide a safer travel route for cyclists. Thus, riding e-bikes may be safer than the group perceives. Other cities have restricted biking speed (P. Zhao, personal communication, December 5, 2014). To enforce the speed limit, police officers may deflate bicycle tires. In terms of mechanical restrictions, Omnipay plans to use the smallest adult sized e-bike with motor restrictions limiting the speed to 30 kmph. This means that the electric assistance turns off once travel speeds exceed 30 kmph. Furthermore, e-bikes are generally safer than cars because they use the bicycle lane, which reduces their risk of colliding with a larger vehicle. If students became confident that e-bikes are safe, the user base for e-bikes could grow significantly. Nevertheless, the additional concern of not having insurance may deter students from using an e-bike system even if it addresses safety concerns. The scope of this project does not focus on the details of potential insurance policies.

4.1.4 Deposit Price and Hourly Rate

Deposit price is a deciding factor for students considering e-bike sharing. Mr. Ying Gaofeng, Omnipay's e-bike manufacturer correspondent, projects a minimum safety deposit of 1500 RMB (G. Ying, personal communication, November 24, 2014). When we asked whether students would be willing to deposit 1500 RMB for an e-bike sharing, the response was a unanimous no. Students in the focus group would not deposit such a high amount on their transportation card because it is not secured with their personal information. They were more willing to deposit into a secure account, such as a citizen card. Furthermore, most students agreed they would pay a maximum of 500 RMB. However, negotiating a lower price poses a challenge since 1500 RMB is already subsidized from the original 3000 RMB cost of the e-bike. 1500 RMB is comparatively higher than other e-bike sharing system around the world, Bycyklen at 517 RMB and BiciMAD at 1100 RMB (BiciMAD, 2014; Bycyklen, 2014). BiciMAD also offers a subscription plan that does not require a deposit from the user (BiciMAD, 2014). Similar alternative payment plans may attract users by lowering the deposit commitment. If Omnipay cannot lower the deposit price, it may limit e-bike sharing usage.

Charging to rent an e-bike for the first hour could help offset the deposit cost. The focus group was willing to pay starting the first hour for the e-bike. Omnipay believed that the e-bike sharing program would have to follow the manual bike sharing program, which offers a free first hour and receives funding from the government and advertisements (P. Zhao, personal communication, October 31, 2014). Survey results support this, with 79% indicating they always or sometimes try to return their bike in under an hour. However, we found that most people felt that e-bikes are worth paying a small premium to use. The focus group was willing to pay between 3-10 RMB per hour, especially if it meant reducing the deposit price. The survey supports these findings as well; most respondents who expressed interest in e-bike sharing (4 or 5) were willing to pay an average of 2 or 3RMB per hour. As seen in Figure 4.4, only 4% would take advantage of a free hour. This leaves 96% of the interested e-bike sharing population that is willing to pay per hour to use an e-bike. If e-bike users pay a small hourly rate, the payment could offer an alternative revenue source to reduce the deposit price. Eliminating the free hour for the e-bike system in order to lower the deposit price would likely encourage more users than it loses.

Preferred Payment by Students Interested in E-bike Sharing

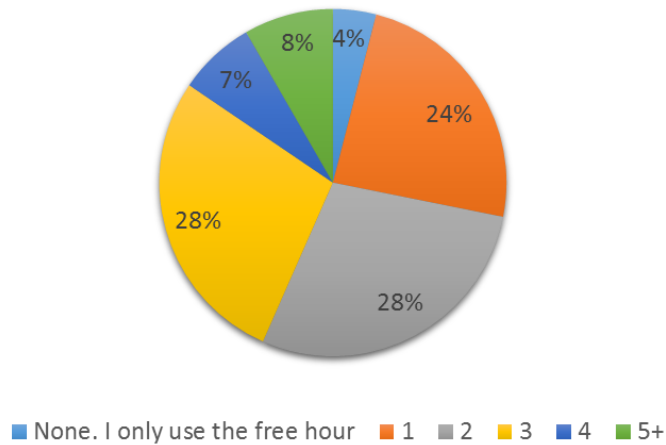


Figure 4.7: Preferred Hourly Payment for E-bike Sharing

4.1.5 Social Implications and Aesthetics

The presence of advertisements and painted color can make rental bicycles unappealing to students. This is because students also consider implications of social status and choose electric bikes based on aesthetics (Shi, 2013). The significance of style differed between the survey and the focus group. Style ranked last in the survey but was emphasized during the focus group. One possible reason is that students perceived the survey to be more formal than the more casual focus group. Responses from our focus group explained that the lack of style deterred students from using the manual bike sharing program. Participants disliked the basket in front of the manual bike as well as the advertisements as shown in Figure 4.5. Omnipay can choose a more favorable color for the new e-bikes. However, removing the advertisements or the storage compartment affects functionality, which may lead to economic consequences. Advertisements provide revenue for the current bicycle sharing system and 32% of surveyed students said that carrying items influenced their choice of transportation. We revealed a picture of the e-bike prototype as shown in Figure 4.6, to gauge student interest in the e-bike Omnipay plans to implement. Perhaps because some students expected an automatic e-bike, they were initially letdown by the presence of pedals on the prototype bike. Nevertheless, they lauded its color and general appearance. Therefore, it is important to consider the social implications of riding an electric bicycle when considering a student audience.

Contrary to the focus group, the survey showed that style was the least chosen consideration when choosing transportation. In the survey, we only provided style as a reason to choose, not as a reason to avoid a mode of transportation. This may have limited the responses we received. Therefore, although style may not be significant as a positive attribute, it may be a deterrent for students. This is perhaps supported by the fact that only 2% of the students surveyed used public bikes daily. It is possible that respondents did not have the bike sharing system in mind when answering this question.



Figure 4.9: Hangzhou Manual Bike



Figure 4.8: Electric Bike Prototype

4.1.6 Traffic

We also considered what the population looks for in transportation to help Omnipay and e-bikes appeal to a wider audience. The survey identified the aspects people weigh most. Figure 4.7 shows the factors for choosing transit. While convenience is the most common factor, traffic is the second. We will address convenience in Section 4.3 as it is best addressed with infrastructure. A substantial proportion of respondents, 513 of the 680, consider traffic in choosing their transportation. Fortunately, e-bikes travel in the designated bike lane, which allows them to bypass the majority of traffic. The advantage of bypassing traffic can be associated with convenience. The 75% of users who worry about traffic must include some Xiasha residents who were unsure or dismissive of e-bike sharing. This provides a selling point to convert some non-users into users.

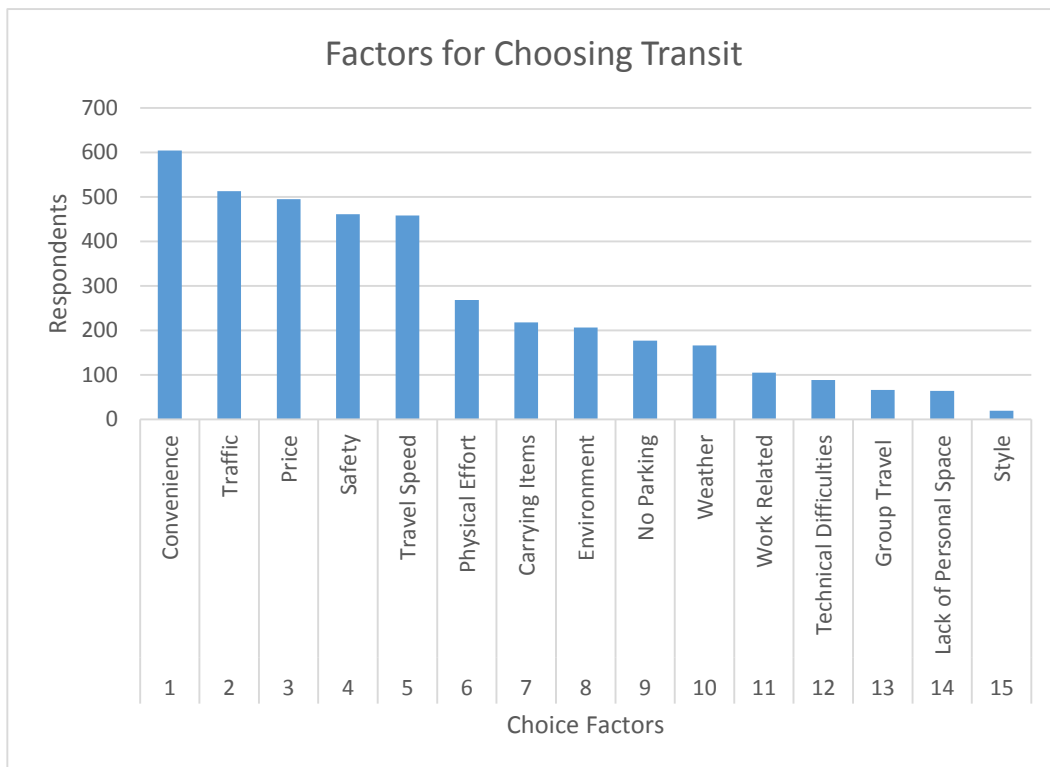


Figure 4.10: Factors for Choosing Transit

4.2 Environmental Interest: Long/Short Term Effects

Overall, a new e-bike sharing system will benefit the environment in Xiasha. How much positive influence e-bikes will have on the entire environment is partially dependent on the types of transportation that e-bikes displace. If electric bikes replace private automobiles as students' primary mode of transportation, then this can improve both traffic conditions and air quality for students in Xiasha.

However, we have considered negative outcomes. E-bikes in China might rely on coal, hydropower, gas, or nuclear generated electricity (Cherry, Weinert and Xinmiao, 2009). Coal represents 75% of energy production in China; however, China is moving towards greener energy. This means that e-bikes will not emit carbon dioxide and other pollutants in the city, although they indirectly contribute to coal pollution outside of the city through electricity production. Thus e-bike sharing in Xiasha would benefit students by displacing air pollution to less populated regions near coal power plants. Health benefits tied to improved air quality in Xiasha may appeal to students. On a scale of 1 (Not Important) to 5 (Very Important), 83% of surveyed students consider environmental friendliness important. On the other hand, our focus group showed that students may be reluctant to participate in e-bike

sharing because battery production and coal generated electricity contributes to the long term increase of lead and air pollution (Cherry et al., 2009).

4.2.1 Private Car Users' Interest in E-bike Sharing

If e-bike sharing successfully reduces automobile traffic, then it is a partial solution to urban air pollution. Compared to automobiles, e-bikes require significantly less energy, and emit less air pollutants (Cherry, et al., 2009). On the other hand, e-bike battery production exacerbates lead pollution significantly more than automobiles. According to survey responses, the majority of student who travel by private cars daily (83%) may consider the overall impact on the environment (a 3, 4, or 5 on a scale of 1 to 5, not important to very important). Survey responses also show that 31% of the student population or 58,900 students use private cars daily. However, we noted that Zhejiang University of Finance and Economics (ZUFE) accounts for the majority of private car usage. ZUFE would be a prime location for a new e-bike system to displace private automobiles, In Table 4.1, we consider the common modes of daily transportation by students in the Xiasha Higher Learning Garden. We found that students who use the current public bike sharing system daily showed the greatest percentage of interest in e-bike sharing; however, considering the number of respondents, walkers represented the greatest number of interested users. The survey revealed that 38% of daily private car users expressed interest e-bike sharing. We estimate that e-bike sharing can potentially displace 5630 cars from the road in Xiasha. This would increase e-bikes positive influence on the environment.

Table 4.1: Daily Transportation Usage and E-bike Interest

| Daily Users | Public Bike Sharing | Private Bike | Bus | Walking | Private Car |
|---|---------------------|--------------|------|---------|-------------|
| Number of Respondents | 16 | 98 | 35 | 635 | 53 |
| Estimated Population* | 4470 | 27400 | 9780 | 177000 | 14800 |
| Interest in E-bike Sharing (4,5) | 63% | 44% | 37% | 40% | 38% |
| Estimated Potential Users* | 2820 | 12000 | 3620 | 71000 | 5630 |
| * These numbers are only estimates. We calculated these numbers assuming that our survey was an accurate representation of the 190,000 students in Xiasha Higher Learning Garden. | | | | | |

4.2.2 Public Shared Bicycle Users' Interest in E-bike Sharing

Pursuing environmental interests, a new electric bike sharing system should not replace, but rather complement the manual bike sharing system. According to Cherry, because e-bike and manual bike sharing benefit users in different ways, they can share a market without being mutually exclusive (C. Cherry, personal communication, October 11, 2014). E-bikes are unlikely to replace manual bicycles. Instead, e-bike sharing will complement the manual bike sharing system by enabling students to travel longer distances. In turn, the new e-bike sharing system can benefit from being connected to the existing bike sharing customer base. According to our survey, the majority of bike sharing users (63%) showed strong support for e-bike sharing. Additionally, e-bike sharing appeals to some students who currently do not participate in bike sharing. In fact, 43 of the 119 students or 6% of the entire population said that they do not rent bikes, but expressed interest in e-bike sharing. This means that e-bike sharing could act as an extension of the current system and increase the number of students in Xiasha who use public transit.

4.2.3 Pedestrian Interest in E-bike Sharing

Displacing walking is not beneficial for the environment and traffic. Our survey revealed that of 93% of students walk daily, 40% of students are interested in e-bike sharing. The study at UTK found that e-bike sharing displaced walking the most (Langford, et al., 2013). Considering the student population of UTK (40,000) compared to Xiasha (190,000), e-bike sharing may replace walking in greater numbers, but at a lower ratio of e-bike users to pedestrians. In the short term, displacing walking will not benefit the overall environment. This is because the power that charges e-bikes is produced by coal power plants. However, if students begin to use e-bikes now, then they may continue to rely on the system as professionals. Professionals are currently the largest e-bike sales market according to our interview with Ying Gaofeng of GreenShare (include brief company description).

4.3 Infrastructure

We considered the Xiasha District's current transportation infrastructure in order to understand if the district could support e-bike sharing. We found that the district has designated bike lanes as well as taxis, buses, manual bike sharing, and several subway station stops. Using a combination of methods, we analyzed how e-bikes could integrate into the current transportation infrastructure.

4.3.1 Station Placement

The optimal location for e-bike stations are at current manual bicycle sharing stations. According to the map we created (Figure 4.11), the city has located 75% of Xiasha's bike

sharing stations near subway or bus routes. The black marks represent manual bicycle sharing stations. By integrating e-bikes into these bike sharing stations, the e-bikes can become an extension of the current transportation network in Xiasha. We found that 26% of students transfer between the subway and the current bicycle sharing system, and 35% reach bicycle stations by walking. Students listed these two types of transfers most often from a list that included: subway, bus, taxi, private car, walking, or none of the above. Therefore, combining e-bike stations with manual stations within walking distance of campuses and near subway systems would provide accessible connections for students.

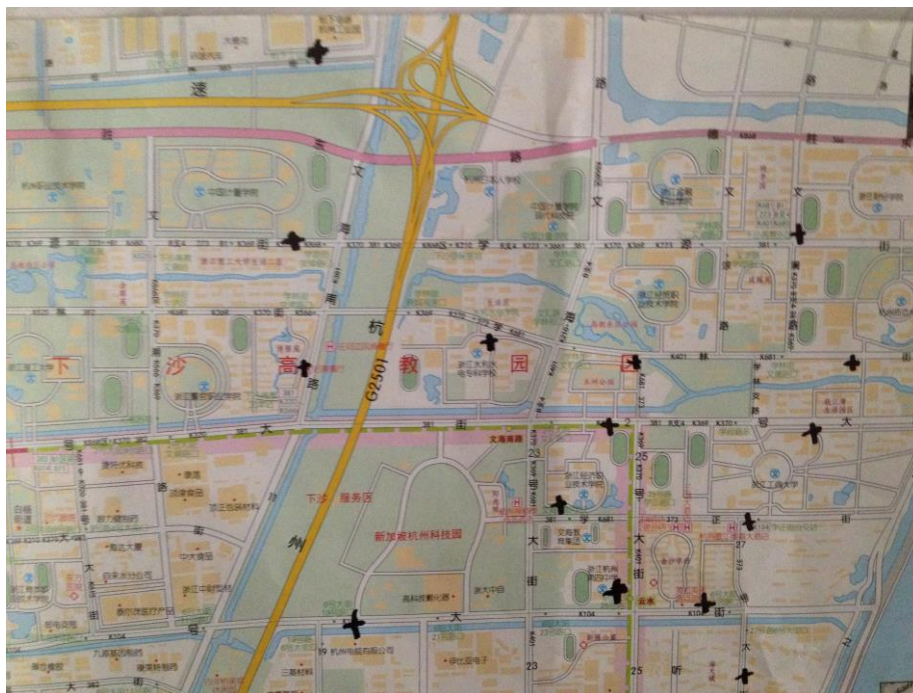


Figure 4.11: Map Generated using iCity Zeonic iPhone Application

Having e-bike stations in close proximity to campuses is important because 99% of students live on campus in the Xiasha Higher Learning Garden (XHLG). As explained previously, walking is the most common mode of transportation used by students. Consequently, stations within walking distance would be most convenient for students. Students ranked convenience as the most important factor when choosing a mode of transportation. Accessibility is tied to convenience; the closer stations are to points of interest, the more convenient it is to use the mode of transportation (Naess, 2012). Currently, Xiasha has at least 11 manual bike stations on roads adjacent to universities, integrating e-bikes with these stations would improve. The city could modify these stations to support e-bikes. This is because the current infrastructure supplies electricity to the manual bike

stations to power the parking pylon card readers. Ying Gaofeng of GreenShare, and Peter Zhao and Chao Huang of Hangzhou Omnipay Co. Ltd, believe that the stations have the electrical capacity to charge e-bikes.

By connecting e-bikes with bike stations near the subway, students can easily travel outside of the Xiasha District. The Gaosha Road and Wenze Road metro stations and the planned Wenhai South Road and Yunshui stations border the university district in Xiasha. These subway stations also connect students to the Coach Center and East Railway Station stops on Subway Line 1, both of which provide travel out of the city via bus and rail, respectively.

In Copenhagen, Denmark, the Bicyklen electric bike sharing system acts as an extension to the current public transportation network. The city placed the current twenty e-bike stations near other public transit stations. At the University of Tennessee-Knoxville in the United States, the cycleUshare program's Presidential Court station received 91% of all trips, which researchers attributed to its prime location near residence halls. Considering these two systems, if Xiasha provided accessible e-bike stations that connected campus to subway stations, then it would also continue to solve the first/last mile issue of public transportation. The current manual bike sharing also strives to solve the first/last mile problem and could act as a framework for the e-bike sharing network. We defined this problem earlier as the distance between the initial or final destination and public transportation.

4.3.2 Station Distribution

The distribution of e-bike stations may affect the success of e-bike sharing in Xiasha. The two main risks of e-bikes are flat tires and dead batteries. If pedal assist electric bikes run out of charge on the battery, they operate as manual bikes. The difference is that e-bikes weigh three times more than manual bikes. Therefore, an uncharged e-bike requires more physical effort to ride than a manual bike. The survey revealed that 18% of students considered e-bikes unreliable and 39% considered physical effort when choosing a mode of transportation. With this in mind, distribution of e-bike stations and quality of e-bike equipment become important in order to minimize the distance users will have to travel if their e-bike encounters a problem like a depleted battery or flat tire.

Chapter 5: Conclusion and Recommendations

The intent of this project was to determine the feasibility of an electric bicycle sharing system in the Xiasha District of Hangzhou. In order to accomplish this goal, we identified three objectives to organize methods and provide a framework for discussion. By researching student demand for electric bikes, we determined if students would be a viable user base for the system. Through understanding the environmental long and short effects of e-bikes, we determined if Hangzhou Omnipay Co., Ltd. could use environmental benefits to gain governmental support. And by considering the current transportation infrastructure, we determined if Xiasha could support the addition of e-bikes into its transportation network. The project findings lead us to the following conclusion: An e-bike sharing system is feasible in the Xiasha District of Hangzhou.

The findings show that there is sufficient potential demand in Xiasha for an e-bike sharing system. Over half of the population would likely use the system, enough to justify its implementation. Despite this, there are several aspects that impede the number of people willing to use the system. We have several recommendations to increase the size of the potential user base and ensure that the system is a success.

Deposit

The 1500 RMB deposit required for e-bike sharing would deter students from renting an e-bike. In order to lower the price barrier for students, we recommend finding ways to reduce and/or provide personal security for the deposit. Students would only consider depositing into a multi-functional card that is secured with their personal information, like their citizen card. If a new e-bike service could use this type of card for payment, then more students may consider e-bike sharing. Two potential options to offset the deposit price are to charge for the initial hour or offer subscription payment plans. In Xiasha, the majority of students are willing to pay for the e-bikes initial hour. By charging a small hourly rate, the system could lower the deposit price. Hourly rates ranging from 1 to 3 RMB appealed to most students. Overall, the system would gain many more users from having a lower deposit price than it would lose from charging for the first hour. In addition, we recommend offering a subscription alternative if lowering the deposit is not viable. E-bike sharing systems, such as Bycyklen in Copenhagen, offer subscription plans to decrease the required deposit (Bycyklen, 2014). If Omnipay records the user's information, the system could charge the

user if something should happen to the e-bike. By offering a subscription plan, whether it be annually or monthly, Omnipay could reduce or provide an alternative to deposits.

Safety

Omnipay should promote safety in order to mitigate risks. Students expressed high concern for e-bike safety. Omnipay has already taken steps to increase the safety of a rental e-bike, choosing the smallest adult sized model and installing restrictions to the electric motor. To further increase user safety, we recommend offering helmets with the rental. Since attendants manage the current bike stations, it is reasonable to extend their responsibilities to encourage safety by handing out helmets to those who want them. Students consider the lack of insurance a disincentive. Further studies should investigate the viability of incorporating insurance into the deposit price.

Cell Phone Charging

Cell phone charging was well received during the focus group and installing it would increase the popularity of e-bikes. However, if doing so would increase the cost of the e-bike dramatically, it should be forgone to keep the cost of the deposit low.

Potential Environmental Benefits

E-bike sharing will improve both traffic conditions and air quality for students in Xiasha, only if e-bikes displace more private automobiles than manual bicycles or walking. Compared to automobiles, e-bikes emit minimal direct air pollutants and maximize road space (Weinert, 2008). Depending on the location of their university, students may have different preferences for transportation. Further studies should identify which universities have the highest car user population. Omnipay should implement these locations to target the most car users. However, e-bike sharing is not as environmentally friendly as bike sharing because e-bikes rely on electricity produced at coal plants (Cherry, Weinert & Xinmiao, 2009). Fortunately, e-bike sharing will not replace bike sharing because they offer different travel advantages, according to Cherry (C. Cherry, personal communication, October 11, 2014). The new system will complement bike sharing instead, enabling students to travel farther away with less effort. In turn, the new system can benefit from sharing the public bike user base. On the other hand, rental bikes may displace walking, as observed in University of Tennessee-Knoxville (Langford, et al., 2013). Displacing walking may have environmental repercussions. If students participate in e-bike sharing, they may be more inclined to continue renting e-bikes as professionals; thereby, e-bike sharing will reduce the number of automobiles in the long term.

Style

We recommend that Omnipay consider aesthetics when determining the appearance of the e-bikes for the sharing program. Three main suggestions stood out to make the bikes as appealing as possible. The first is to choose a popular paint color. Students in the focus group approved of the slick, white look of the prototype, and so we recommend a neutral color that would not offend any tastes. The second would be offering e-bikes without a basket. Of course, many people might still desire the use of a basket so Omnipay should not forego the basket entirely. Providing some basketless e-bikes, however, would give riders the option. Also, if there are enough attendants and volunteers, Omnipay could consider offering detachable baskets. The third recommendation is to find a way to utilize advertisements without discouraging users. One way would be to display ads on the handlebars just for the riders that are not visible to bystanders. This will limit the number of people who can see the advertisement, but the ad will receive much closer attention from the rider and potentially be a more valuable advertising slot. If a tablet is attached to the e-bike, it could also display advertisements on the navigation screen. The additional revenue from this could offset the need to put advertisements on the wheel or basket of the bike as is done with the manual bikes.

Public Outreach Campaign

As a new system, public outreach may be necessary to attract potential users. We recommend an initial marketing campaign to advocate for the advantages of e-bike sharing. For example, rental e-bikes can bypass traffic in the bike lane. Traffic is a challenge in Hangzhou and many students choose modes of transportation that enable them to avoid it. Only 51% were interested in e-bike sharing, although 75% of students considered traffic as a major hindrance. A small advertisement campaign to educate these people would be fruitful to the success of the system. This could perhaps be something as simple as a pamphlet at the e-bike station or a promotion campaign through WeChat. The scope of this project, however, did not include public service announcements or advertising strategies; this should be left to Omnipay's discretion or possibly a future IQP.

Station Placement

We recommend that Hangzhou Omnipay Co. Ltd combine electric bike charging stations with current manual bike sharing stations. This allows e-bike sharing to capitalize on Xiasha's existing transportation infrastructure. Manual bike sharing stations already have a connection to the power grid and the city has located most near subway and bus routes. This

means that manual bike stations can satisfy the charging requirements for e-bikes as well as incorporate e-bikes into the current transportation network.

Distribution of Stations

We recommend that Omnipay consider the distribution of e-bike stations when selecting station placement. Because dead batteries are one of the biggest issues for electric bike, having a well distributed placement of stations can reduce the risk of users losing electric capabilities while riding. We attribute this to the fact that a higher density of stations could reduce trip length, and thus battery usage. Appropriate distribution of stations can also help optimize station accessibility and availability of e-bikes by providing convenient options for students. As convenience is the most important factor for choosing transportation, improving accessibility and availability could raise more student interest.

Summary

In conclusion, an electric bicycle sharing system is feasible in the Xiasha District of Hangzhou. There is student demand in the Xiasha District for e-bike sharing, e-bikes have the potential to be positively beneficial to the environment in Xiasha, and the Xiasha District has the appropriate infrastructure to support an e-bike sharing system. The Xiasha District has the capability of producing the first successful e-bike sharing system in China, which can perhaps serve as a model for other cities. It is important to note however that even though the Xiasha District has user interest and appropriate infrastructure, without the support of the government, the system may face challenges beyond the scope of this project. Government support is instrumental in the success of Hangzhou's manual bike sharing system, and as our literature study revealed, systems without a significant amount government involvement are more difficult to maintain (see Wuhan, 2.2.3). In addition, as e-bike sharing is a relatively new concept, there may be other, unforeseen obstacles that the Xiasha District will have to face.

Further Studies

We recommend that further studies continue to delve more deeply into student interest and concerns for e-bike sharing. Our study was limited to five of the fourteen universities in the Xiasha Higher Learning Garden (XHLG), and as such our data is not the most accurate representation of the entire student population. For example, almost all of the daily car users in the survey came from Zhejiang University of Finance and Economics. In addition to expanding the survey population, we suggest more focus groups, perhaps at each university in the XHLG. More focus groups could allow researchers to understand the interests of students at each university, and make connections between students' views at

different schools. Finally, as the e-bike sharing programs in Copenhagen (Bycyklen) and Madrid (BiciMAD) become more established, researchers should conduct a deeper analysis of the advantages and disadvantages of the systems.

References

- 1Hangzhou.com. (2009). *Hangzhou Economic and Technological Development Zone-Xiasha*. Retrieved from http://www.chinadaily.com.cn/m/hangzhou/e/2009-08/06/content_8536397.htm
- 1Hangzhou.com. (2010). *All roads lead to Hangzhou*. Retrieved from http://www.chinadaily.com.cn/m/hangzhou/e/2010-01/27/content_9385185.htm
- Apple Inc. (2014). [Interactive map of Hangzhou]. *Apple iOS 8 Maps*. Retrieved from www.apple.com/tw/ios/maps/
- Aragon, L., Humbaraci, A., & Papotto, J., (2011). *Feasibility Study of Car-sharing Service in Hangzhou, China* (Undergraduate Major Qualifying Project No. E-project-081211-112615). Retrieved from Worcester Polytechnic Institute Electronic Projects Collection: <http://www.wpi.edu/Pubs/E-project/Available/E-project-081211-112615/>
- Bach, U. (2014). *The new Copenhagen city bike: BYCYKLEN*. Visit Copenhagen: The Official Website. Retrieved from <http://www.visitcopenhagen.com/copenhagen/new-copenhagen-city-bike-bycyklen>
- Baidu. (2014). [Interactive map of Hangzhou]. *Baidu Maps*. Retrieved from map.baidu.com/
- Basch, C. H., Ethan, D., Rajan, S., Samayoa-Kozlowsky, S., & Basch, C. E. (2014). *Helmet use among users of the Citi Bike bicycle-sharing program: a pilot study in New York City*. *J Community Health*, 39(3), 503-507.
- BiciMAD. (2014). *What is BiciMAD?* Retrieved from <http://www.bicimad.com/>
- Bonopark. (2014). *BiciMAD: Madrid's Public Electric Bicycle System*. Retrieved from www.madrid.es
- Bycyklen. (2014). *Bycyklen*. Retrieved from <http://bycyklen.dk/en/>
- Campbell, A. A. (2012). *Factors Influencing the Choice of Shared Bicycles and Electric Bicycles in Beijing-- A Stated Preference Approach* (Master's Thesis). University of Tennessee-Knoxville, Tennessee.
- Chaoyang District, Beijing, China. (2001). *A Sketch of Chaoyang*. Retrieved from <http://www.bjchy.gov.cn/english/asc.htm>
- Chen, S. (2009). *Bicycle Rental Card*. Retrieved from http://old.jfdaily.com/newspaper/xwcb/page_4/200911/t20091106_793852.html
- Chen, S. (2010). *How Long can Free Bike Rental Implement*. Retrieved from http://newspaper.jfdaily.com/shfzb/html/2010-01/26/content_270562.htm

Chen, Y. (2014). *Hangzhou subway Line 2 started at 9:35 this morning*. Retrieved from <http://zzhz.zjol.com.cn/system/2014/11/24/020375193.shtml>

Cherry, C., Weinert, J., & Xinmiao, Y. (2009). *Comparative environmental impacts of electric bikes in China*. *Transportation Research Part D: Transport and Environment*, 14(5), 281-290. Retrieved from <http://www.sciencedirect.com/science/article/pii/S1361920908001387>

Cherry, C., Worley, S., & Jordan, D. (2010). *Electric Bike Sharing--System Requirements and Operational Concepts*. Knoxville, TN: United States. Dept. of Energy. Office of Scientific and Technical Information.

Cherry, C. Interview 10/11/2014

China Jiliang University. (2014). *School General Information*. Retrieved from: <http://www.cjlu.edu.cn/>

Cui, L. (2006). *Laws and Standards of Electric Bicycle*. Retrieved from http://www.gd.xinhuanet.com/newscenter/ztbd/2006-09/01/content_11170524.htm

cycleUshare (2014). *E-Bike Share at UTK: The nation's first fully automated electric bicycle sharing system*. Retrieved from: <http://www.cycleushare.com/>

De la Peña, B., & Albright, R. (2013). *Catalyzing the New Mobility in Cities: A Primer on Innovative Business and Service Models* [Primer]. New York: Foundation Strategy Group. (pp. 12-13)

Denmark Government. (2014). *Facts and Statistics*. Retrieved from <http://denmark.dk/en/quick-facts/facts/>

Du, W., Yang, J., Powis, B., Zheng, X., Ozanne-Smith, J., Bilstone, L., & Wu, M. (2013). *Understanding on-road practices of electric bike riders: An observational study in a developed city of China*. *Accident analysis and prevention*, 59, 319.

Emancipation Daily Journal. (2009). *Shanghai Tries to Build the Public Bike Rental System*. Retrieved from <http://www.cupta.net.cn/Details.aspx?ID=14212>

Fan, Y. (2008). *Shanghai Trial Free Bicycle Rental Takes the Lead in 8 Colleges*. Retrieved from <http://news.qq.com/a/20080109/002975.htm>

Feng, S., Li, Q. (2013). *Car Ownership Control in Chinese Mega Cities: Shanghai, Beijing and Guangzhou*. Retrieved from http://ltaacademy.lta.gov.sg/doc/13Sep040Feng_CarOwnershipControl.pdf

Fogelberg, F. (2014) *Solar Powered Bike Sharing System with Electric Bikes - An overview of the energy system* (Master's Thesis). Retrieved from Department of Environmental Systems Analysis, Chalmers University of Technology. Retrieved from <http://studentarbeten.chalmers.se/publication/200760-solar-powered-bike-sharing-system-with-electric-bikes-an-overview-of-the-energy-system-and-the>

Gao, S., Zhou, F., Gong, W., Tao., S & Feng, B. (2012). *The Design of Electric bicycle solar charging system*. Retrieved from <http://www.cqvip.com/qk/91837a/201204/41845862.html>

Garcia-Palomares, J. C., Gutierrez, J., & Latorre, M. (2012). *Optimizing the location of stations in bike-sharing programs: A GIS approach*. *Applied Geography*, 35(1-2), 235-246. Retrieved from <http://www.sciencedirect.com/science/article/pii/S0143622812000744#bib49>

Gobike. (2014). *Copenhagen, Denmark*. Retrieved from <http://www.gobike.com>

Goldenet. (2012). *Goldenet*. Retrieved from www.goldenetbj.cn

Gonzalez, L. (2014). *BiciMAD. Madrid Gets A (Crazy) Electric Bike Sharing Program*. *Clean Technica*. Retrieved from <http://cleantechnica.com/2014/06/29/bicimad-madrid-gets-crazy-electric-bike-sharing-program/>

Gribben, C. (1996) "Debunking the Myth of EVs and Smokestacks." *Electro Automotive*. N.p., 26 Oct. 1996. Web. 16 Dec. 2014. Retrieved from <http://www.electroauto.com/info/pollmyth.shtml>

Guo, R. (2008). *The current situation of the development of electric bicycle and the requirement of battery*. Retrieved from <http://www.doc88.com/p-984346832459.html>

Hancock, Tanner. (2014). *University denies funding for electric bike sharing*. *The Daily Beacon*. Retrieved from <http://utdailybeacon.com/news/2014/jul/30/university-denies-funding-electric-bike-sharing/>

Hangzhou Dianzi University. (2014). *School General Information*. Retrieved from: http://www.hdu.edu.cn/index_pc.html

Hangzhou.gov.cn. (2009). *Xiasha New Town*. Retrieved from <http://www.hangzhou.gov.cn/main/zpd/English/Context/CityNewZones/T197475.shtml>

Hangzhou Government (2014). *About Hangzhou*. Retrieved from <http://eng.hangzhou.gov.cn/main/zpd/English/AboutHangZhou/T302691.shtml>

Hangzhou MTR. (2013). *Hangzhou MTR*. Retrieved from <http://www.mtrhz.com.cn/>

Hangzhou Normal University. (2014, September 15). *School General Information*. Retrieved from <http://www.hznu.edu.cn/>.

Hangzhou Public Transport Group Co., Ltd. (2009). *Company Profile- Hangzhou Public Transport Group Co., Ltd*. Retrieved September 21, 2014, from http://www.hzbus.com.cn/en/about.aspx?c_kind=706&c_kind2=707&c_kind3=1078

Hangzhou Vocational & Technical College. (2014). *School General Information*. Retrieved from: <http://www.hzvtc.edu.cn/>

Hangzhou Yuying College of Vocational Technology. (2014). *School General Information*. Retrieved from: <http://www.zjyyc.com/>

hzrb.cn. (2010, May 6). *Hangzhou HEDA: Industrial Upgrading and Regional Value Accelerating*. Retrieved from <http://ads-hzrb.hangzhou.com.cn/system/2010/05/06/010615579.shtml>

Investment Promotion Agency of Ministry of Commerce (CIPA) (2008, June 16). *Quality Improvement Is Stressed in the Innovative Investment Invitation Platform of Hangzhou Economic and Technological Development Zone*. Retrieved from http://www.fdi.gov.cn/1800000121_37_36367_0_7.html

Ji, S., Cherry, C. R., Han, L. D., & Jordan, D. A. (2013). *Electric bike sharing: simulation of user demand and system availability*. *Journal of Cleaner Production*. Retrieved from <http://www.sciencedirect.com/science/article/pii/S0959652613006276>

Jiang, Q. (2011). *The development of bike sharing: A comparison of the Stockholm and Hangzhou cases* (Master's Thesis). Royal Institute of Technology, Stockholm, Sweden.

Kaiser, K. (2012, July-August). *Closing the gap--bike shares help complete the 'last mile': in the right conditions, bike-share programs can help mobilize a city*. *Mass Transit*, 38(5), 20+. Retrieved from <http://go.galegroup.com.ezproxy.wpi.edu/>

Kang, L., & Biao, C. (2012). *Lessons from Developing Public Bicycle System in Hangzhou*. Remote Sensing, Environment and Transportation Engineering (RSETE), 2012 2nd International Conference on, 1-4.

Klein, J., Liu, S., Lynch, K., & Manternach, A. (2014). *Business Biking in Croydon*. (Undergraduate Interactive Qualifying Project No. E-project-062714-110905). Retrieved from Worcester Polytechnic Institute Electronic Projects Collection: <http://www.wpi.edu/Pubs/E-project/Available/E-project-062714-110905/>

Langford, B. C. (2013). *A comparative health and safety analysis of electric-assist and regular bicycles in an on-campus bicycle sharing system*. (Doctor of Philosophy), University of Tennessee, Knoxville.

Langford, B., Cherry, C., Yoon, T., & Smith, D. (2013). *North America's First E-Bikeshare*. *Transportation Research Record: Journal of the Transportation Research Board*, 2387(1), 120-128.

Larsen, J. (2013, July). *Pedal power goes global*. *USA Today*. 142(2818), 24+.

Laursen, L. (2014a). *Copenhagen Pioneers Smart Electric-Bike Sharing* - IEEE Spectrum. Retrieved from: <http://spectrum.ieee.org/transportation/alternative-transportation/copenhagen-pioneers-smart-electricbike-sharing>

Laursen, L. (2014b). *Madrid Begins Electric Bike Sharing* - IEEE Spectrum. Retrieved from: <http://spectrum.ieee.org/tech-talk/transportation/alternative-transportation/madrid-begins-electric-bike-sharing>

Let's get down to business! To defeat the Huns

- Lebetkin, M. (2014). *Best bike-sharing cities in the world*. USA Today. Retrieved from <http://www.usatoday.com/story/travel/destinations/2013/10/01/best-cities-bike-sharing/2896227/>
- Lewington, L. (2014). *Hiring an electric 'smart' bike in Copenhagen*. Retrieved from: <http://www.bbc.com/news/technology-28261140>
- Li, J. (2012). *Beijing Public Bike Sharing System is Free Within an Hour*. Retrieved from: <http://bj.yzdsb.com.cn/system/2012/10/10/012021417.shtml>
- Li, Q. (2014). *The modes of government guidance for public bicycle operation and state-owned company operation: a case study of Hangzhou city in China*. Urban Transport XX, 138, 247-253.
- Lin, J. (2012). *North part of Hangzhou Subway Line 2 will Open in 2017*. Retrieved from: http://www.zj.xinhuanet.com/newscenter/focus/2012-09/06/c_112975942.htm
- Lin, S., He, M., & Tan, Y. (2008). *Comparison Study on Operating Speeds of Electric Bicycles and Bicycles: Experience from Field Investigation in Kunming, China*. Transportation Research Record: Journal of the Transportation Research Board, 2048(1). 52-59.
- Liu, L. (2012). *Non Beijing citizens can rent public bikes now*. Retrieved from: <http://gov.163.com/12/1016/11/8DUDLF5V00234IJM.html>
- Liu, Y. (2013). *Find a Rental Bicycle Card Application Place*. Retrieved from <http://bjyouth.y.net.com/3.1/1304/09/7935746.html>
- Long, M. (2012). *Beijing Retried Public Bicycle Sharing System By Government Operations*. Retrieved from: http://www.cnr.cn/djxw/201206/t20120618_509948948_1.shtml
- Madrid. (2014). *Population evolution - Investor Relations*. Retrieved from: http://www.madrid.org/cs/Satellite?cid=1158849749174&language=en&pagename=Inversor%2FPPage%2FINVE_contenidoFinal
- Ming, L. (2010, September 1). *Xiasha Higher Education Park (the New Century College Town): The Largest Higher Education Park of Zhejiang Province*. Retrieved from <http://it-hzrb.hangzhou.com.cn/system/2010/09/01/010905014.shtml>
- MobiPrize. (2012, May 4). *Judges' Choice 2012: Hangzhou Omnipay Co. Ltd*. Retrieved from <http://mobi prize.com/?p=2248>
- Mobiprize. (2013, July 15). *Hangzhou Omnipay Co., Ltd*. Retrieved from <http://mobi prize.com/?p=1574>
- Næss, P. (2013). *Residential location, transport rationales and daily-life travel behaviour: The case of Hangzhou Metropolitan Area, China*. Progress in Planning, 79(0). 1-50.
- National Renewable Energy Laboratory. (n.d.). *Safety Hazards of Batteries*. Retrieved November 9, 2014.

Omnipay. (2014). *Company Profile- Hangzhou Omnipay Co., Ltd.* Retrieved September 6, 2014, from <http://www.omnipay.cn/english.html>

Rose, G. (2012). *E-bikes and urban transportation: Emerging issues and unresolved questions*. *Transportation*, 39(1), 81-96.

School of Economics and Trade. (2014). *School General Information*. Retrieved from: <http://det.zjvcc.cn/>

Shaheen, S., Zhang, H., Martin, E., & Guzman, S. (2011). *China's Hangzhou Public Bicycle*. *Transportation Research Record: Journal of the Transportation Research Board*, 2247, 33-41.

Shi, L. (2013). *Electric consumption*. Retrieved from http://www.qqddc.com/html/news/201302/news_27075.html

Song, J. (2013). *Public Bicycles in Minhan District are no Longer Free*. Retrieved from: <http://sh.sina.com.cn/news/g/2013-02-21/084335066.html?qq-pf-to=pcqq.c2c>

Standardization administration of the People's Republic of China (1999). *General technical standards of electric bicycles (GB17761-1999)*. Chinese Standards Publisher, 1999.

Tang, Y. (2011). *Bike-Sharing Systems in Beijing, Shanghai, and Hangzhou and Their Impact on Travel Behavior*. Shanghai, China: Department of Urban Planning, Tongji University. Retrieved from http://www.ecf.com/wp-content/uploads/Tang-Yang-Bike-sharing-Systems-in-Beijing-Shanghai-and-Hangzhou_.pdf

The Central People's Government of the People's Republic of China. (2009). *Beijing Municipal People's Government Continue to Implement the Traffic Regulation Law*. Retrieved from: http://www.gov.cn/gzdt/2009-04/06/content_1278637.htm

The people's government of Beijing. (2014). *Peak area Restrictions in Peak hours*. Retrieved from: <http://www.bjigtgl.gov.cn/publish/portal0/tab62/info52267.htm>

University of Tennessee-Knoxville (2014). *Quick Facts*. Retrieved from <http://www.utk.edu/>

Wang, J. (2012). *Bicycle of Chinese Culture*. Retrieved from <http://www.bwchinese.com/article/1030022.html>

Wang, X. (2014) *Public Bike Rental: Why a Successful in Hangzhou, Defeat in Wuhan*. Retrieved from <http://www.hq88.com/magazine/article/201407/228746.shtml>

WBIR. (2014). *Electric bike sharing program ends at UT*. Retrieved from <http://www.wbir.com/story/news/local/downtown-ut/2014/07/31/electric-bike-sharing-program-ends-at-ut/13422393/>

Webster, K. M., & Cunningham, C. J. (2013). *Preparing for bike-sharing: insight from focus groups and surveys, Chattanooga, Tennessee, 2010*. *Health Promot Pract*, 14(1), 62-68.

Weinert, J., Ogden, J., Sperling, D., & Burke, A. (2008). *The future of electric two-wheelers and electric vehicles in China*. *Energy Policy*, 36(7), 2544-2555.

- Wu, J. (2013). *Hangzhou plans to have 10 subway line in 2020*. Retrieved from: <http://zjnews.zjol.com.cn/05zjnews/system/2013/01/25/019112796.shtml>
- Xie, S. (2014). *Wuhan Public Bike Rental System Paralyzed, Operators Make Money*. Retrieved from <http://news.jxgdw.com/bt/2441129.html>
- Xu, Y. (2012). *Design of Solar Power Electric Bicycle Charging Control System*. Retrieved from <http://wenku.baidu.com/view/d4fdfdb565ce050876321383>
- Yang, J., Hu, Y., Du, W., Powis, B., Ozanne-Smith, J., Liao, Y., Li, N., Wu, M. (2014). Unsafe riding practice among electric bikers in Suzhou, China: an observational study. *British Medical Journal*, 4(1). Retrieved from BMJ Open website: <http://bmjopen.bmj.com/content/4/1/e003902.long#xref-ref-13-1>
- Zeonic (Shanghai) Information Technology Co., Ltd. (2014). [Interactive map of Public Transportation in Hangzhou November 14, 2014]. *iCity China*. Retrieved from <http://wakfo.com/Products.aspx?id=9>
- Zhang, J. (2003). *Electric Bicycle Limited Usage*. Retrieved from <http://www.doc88.com/p-738759748450.html>
- Zhang, S. (2013). *Beijing Develops the Green Traffic Vigorously*. Retrieved from http://cn.chinagate.cn/news/2014-09/20/content_33566333.htm
- Zhejiang Economic & Trade Polytechnic. (2011, August, 15). *School General Information*. Retrieved from: <http://www.zjiet.edu.cn/>
- Zhejiang Financial College. (2014, January). *School General Information*. Retrieved from: <http://www.zfc.edu.cn/>
- Zhejiang Gongshang University. (2014, September 30) *School General Information*. Retrieved from: <http://www.hzic.edu.cn/>
- Zhejiang Police Vocational Academy. (2014). *School General Information*. Retrieved from: <http://www.zjyy.com.cn/>
- Zhejiang Sci-Tech University. (2014, November) *School General Information*. Retrieved from: <http://www.zstu.edu.cn/About/GeneralInformation.html>
- Zhejiang University of Finance & Economics. (2014). *School General Information*. . Retrieved from: <http://www.zufe.edu.cn/>
- Zhejiang University of Media and Communications. (2014). *School General Information*. Retrieved from: <http://www.zjicm.edu.cn/>
- Zhejiang University of Water Resources and Electric Power. (2014, June). *School General Information*. Retrieved from: <http://www.zjweu.edu.cn/>
- Zhou, Z. (2013), *Private Cars Numbers Increased 13 Times in Ten Years in China*. Retrieved from http://www.js.xinhuanet.com/2013-12/02/c_118369194.htm

Appendix A: Chinese Translation of Survey

电动自行车共享的可能性

你好，我们是美国伍斯特理工学院的学生，我们在研究电动自行车共享系统在杭州的可行性。感谢您的时间和参与。

1. 圈出你需要乘坐以下所有交通工具的频率

| | | | | |
|--------|----|----|----|----|
| 地铁 | 每天 | 每周 | 每月 | 从不 |
| 公交汽车 | 每天 | 每周 | 每月 | 从不 |
| 黑车 | 每天 | 每周 | 每月 | 从不 |
| 的士 | 每天 | 每周 | 每月 | 从不 |
| 租汽车 | 每天 | 每周 | 每月 | 从不 |
| 私人电动汽车 | 每天 | 每周 | 每月 | 从不 |
| 私人摩托车 | 每天 | 每周 | 每月 | 从不 |
| 租自行车 | 每天 | 每周 | 每月 | 从不 |
| 私人自行车 | 每天 | 每周 | 每月 | 从不 |
| 私有汽车 | 每天 | 每周 | 每月 | 从不 |
| 走路 | 每天 | 每周 | 每月 | 从不 |

2. 影响您选择交通工具的原因有哪些？每个原因里最多选四个

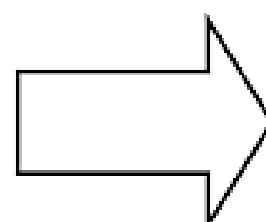
2.1 选择的原因

- 价格
- 方便
- 能携带东西
- 安全
- 速度
- 外观
- 工作需要
- 省力
- 团队需要一起出游
- 环保

2.2 避免的原因

- 交通堵塞
- 贵
- 难驾驶
- 不能携带东西
- 不方便停车
- 不太安全
- 太慢
- 需要体力
- 缺少私人空间
- 天气
- 污染环境

请翻页，后面还有一点，感谢您的耐心与时间 :)



3. 在 7 天里，你有用下列哪项交通工具换乘自行车吗？（杭州公共租借自行车）

- 地铁 的士 走路
 巴士 私人汽车 没有

4. 请在 1 到 5 的范围内圈出您对电动自行车的几个方面的评分

- | | | | | | | | |
|---------------|-----|---|---|---|---|---|-----|
| 4.1 环境对你重要吗？ | 不重要 | 1 | 2 | 3 | 4 | 5 | 重要 |
| 4.2 电动自行车安全度 | 不安全 | 1 | 2 | 3 | 4 | 5 | 很安全 |
| 4.3 电动自行车方便度 | 不方便 | 1 | 2 | 3 | 4 | 5 | 方便 |
| 4.4 电动自行车行驶速度 | 慢 | 1 | 2 | 3 | 4 | 5 | 快 |

4.5 你对公共电动自行车分享感兴趣么？

- 完全不感兴趣 不太感兴趣 不确定 比较感兴趣 很感兴趣

4.6 如果你对租电动自行车很不感兴趣，不太感兴趣或不确定，请选出所有原因。

- 不可靠 贵
 不方便 不安全
 不干净 太吵
 质量差 其他 _____
 没有保险

5. 租电动自行车一小时你最多愿意支付多少钱？

- 不愿意出钱，只愿意免费使用 1 元 2 元 3 元 4 元 5+ 元

6. 职业

- 大学生
 研究生
 全体教员
 其他 _____

7. 当你租用公共自行车时，你都会试着在一小时内的免费时间里就还车了吗？

- 是 有时候 不 我不使用公共自行车租赁

8. 住处

- 住校 不住校 其他区

9. 性别

- 男性
 女性

Appendix B: English Translation of Survey

Feasibility Study of Electric Bicycle Sharing

We are students from Worcester Polytechnic Institute (WPI) in Massachusetts, US. We are researching the feasibility of introducing an electric bicycle sharing system in Hangzhou.

Thank you for your time and participation.

1. How often do you use these modes of transportation? Circle 1 for each mode of transportation.

| | | | | |
|--------------------------|-------|--------|---------|-------|
| Subway | Daily | Weekly | Monthly | Never |
| Public Bus | Daily | Weekly | Monthly | Never |
| Private Van Service | Daily | Weekly | Monthly | Never |
| Taxi | Daily | Weekly | Monthly | Never |
| Public Shared Car | Daily | Weekly | Monthly | Never |
| Private Electric Bicycle | Daily | Weekly | Monthly | Never |
| Private Gas Scooter | Daily | Weekly | Monthly | Never |
| Public Shared Bicycle | Daily | Weekly | Monthly | Never |
| Private Bicycle | Daily | Weekly | Monthly | Never |
| Private Car | Daily | Weekly | Monthly | Never |
| Walking | Daily | Weekly | Monthly | Never |

2. What are the biggest factors that affect your choice of transportation? Select up to four in each category.

2.1 Reasons to Choose

- | | |
|---|---|
| <input type="checkbox"/> Price | <input type="checkbox"/> Work Related |
| <input type="checkbox"/> Convenience | <input type="checkbox"/> Little Physical Effort |
| <input type="checkbox"/> Carrying Items | <input type="checkbox"/> Group Travel |
| <input type="checkbox"/> Safety | <input type="checkbox"/> Good for Environment |
| <input type="checkbox"/> Travel Speed | |
| <input type="checkbox"/> Style | |

2.2 Reasons to Avoid

- | | |
|---|---|
| <input type="checkbox"/> Traffic | <input type="checkbox"/> Too Slow |
| <input type="checkbox"/> Expensive | <input type="checkbox"/> Needs Physical Effort |
| <input type="checkbox"/> Technical Difficulties | <input type="checkbox"/> Lack of Personal Space |
| <input type="checkbox"/> Cannot Carry Items | <input type="checkbox"/> Weather |
| <input type="checkbox"/> No Parking | <input type="checkbox"/> Bad for Environment |
| <input type="checkbox"/> Often Not Safe | |

Please flip over to complete the survey

3. In the last 7 days, did you use a shared bicycle in conjunction with another form of transportation? Check all that apply.

- Subway Taxi Walking
 Bus Private Car None of the Above

4. On a scale of 1 to 5, please circle your rating for the following aspects of electric bicycles.

| | | | | | | | |
|---|----------------|---|---|---|---|---|-----------------|
| 4.1 Is environmental friendliness important to you? | Not Important | 1 | 2 | 3 | 4 | 5 | Very Important |
| 4.2 Safety | Dangerous | 1 | 2 | 3 | 4 | 5 | Very Safe |
| 4.3 Convenience | Not Convenient | 1 | 2 | 3 | 4 | 5 | Very Convenient |
| 4.4 Travel Speed | Slow | 1 | 2 | 3 | 4 | 5 | Fast |

4.5 Would you be interested in an e-bike sharing?

- Definitely not Probably not Not sure I would probably use it I would definitely use it

4.6 If no interest in E-bike sharing, why? (You answered definitely not, probably not, not sure above.) Check all that apply.

- Not Reliable Expensive
 Not Convenient Not Safe
 Not Clean Noisy
 Low Quality Other _____
 No Insurance

5. What is the most you would be willing to pay to rent an electric bicycle for an hour?

- None. I only use the free hour 1 RMB 2 RMB 3 RMB 4 RMB 5+ RMB

6. Occupation

- Undergraduate Student
 Graduate Student
 Faculty
 Other _____

7. When you rent a bicycle, do you try to make sure you return it in under an hour so it is free?

- Yes Sometimes No I don't rent bikes

8. Residence

- On Campus Off Campus Other _____

9. Gender

- Male
 Female

Appendix C: Interview with Ying Gaofeng of GreenShare

Occupation / Title: Technical Manager

Company/Organization: GreenShare Fun

Date of Interview: Nov/24th/2014

Time of Interview: 11:00 AM

Location of Interview: Hangzhou Ompipay Co., Ltd

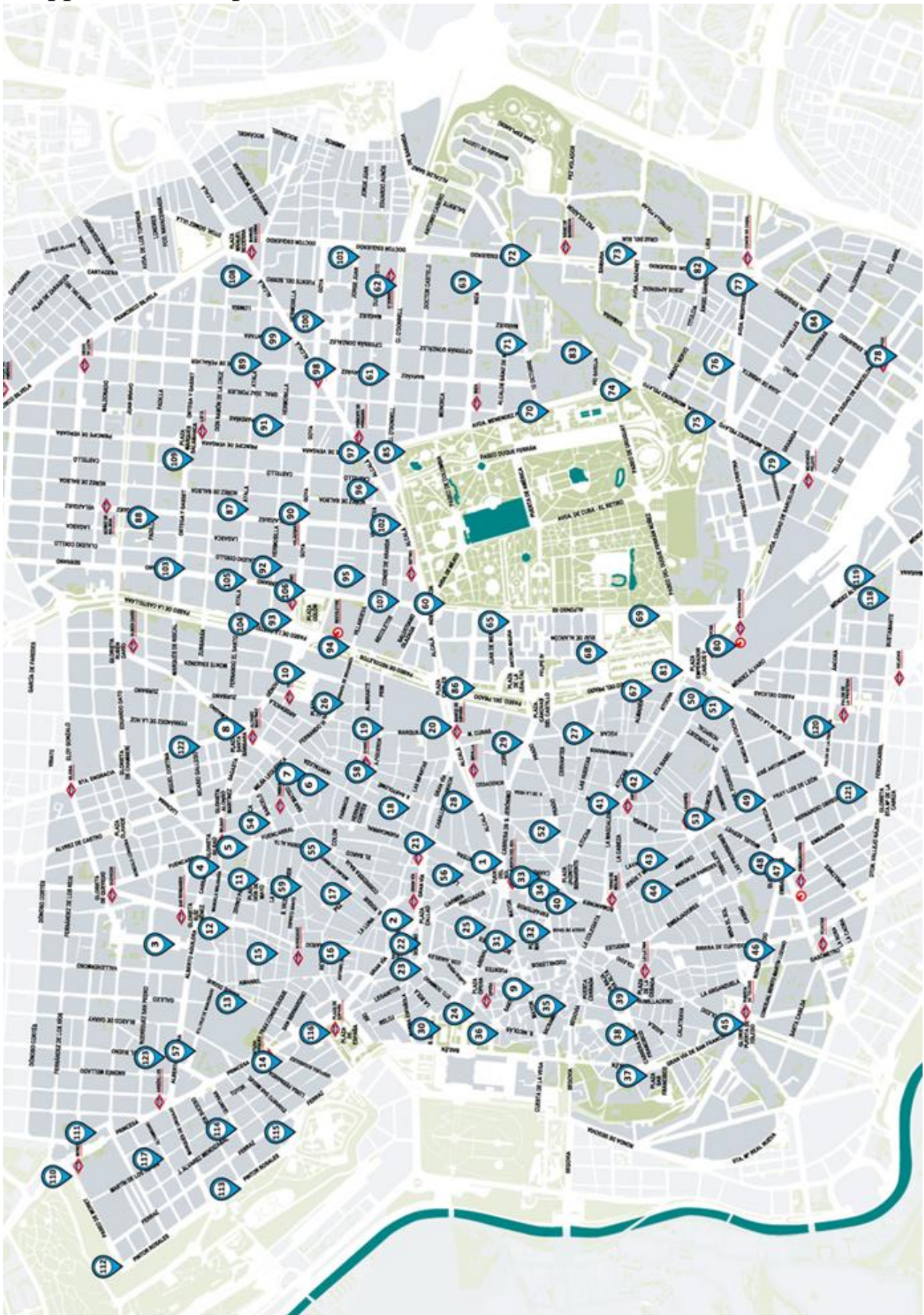
Interviewers: Mr. Ying Gaofeng

1. How much time and power is required to charge the e-bike battery?
2. What is the highest speed of the e-bike?
3. What demographic represents your highest sales?
4. What is the process of getting the e-bike repaired?
5. Costs of each e-bike?
6. Operation costs
7. Would they supply the maintenance for the bikes?

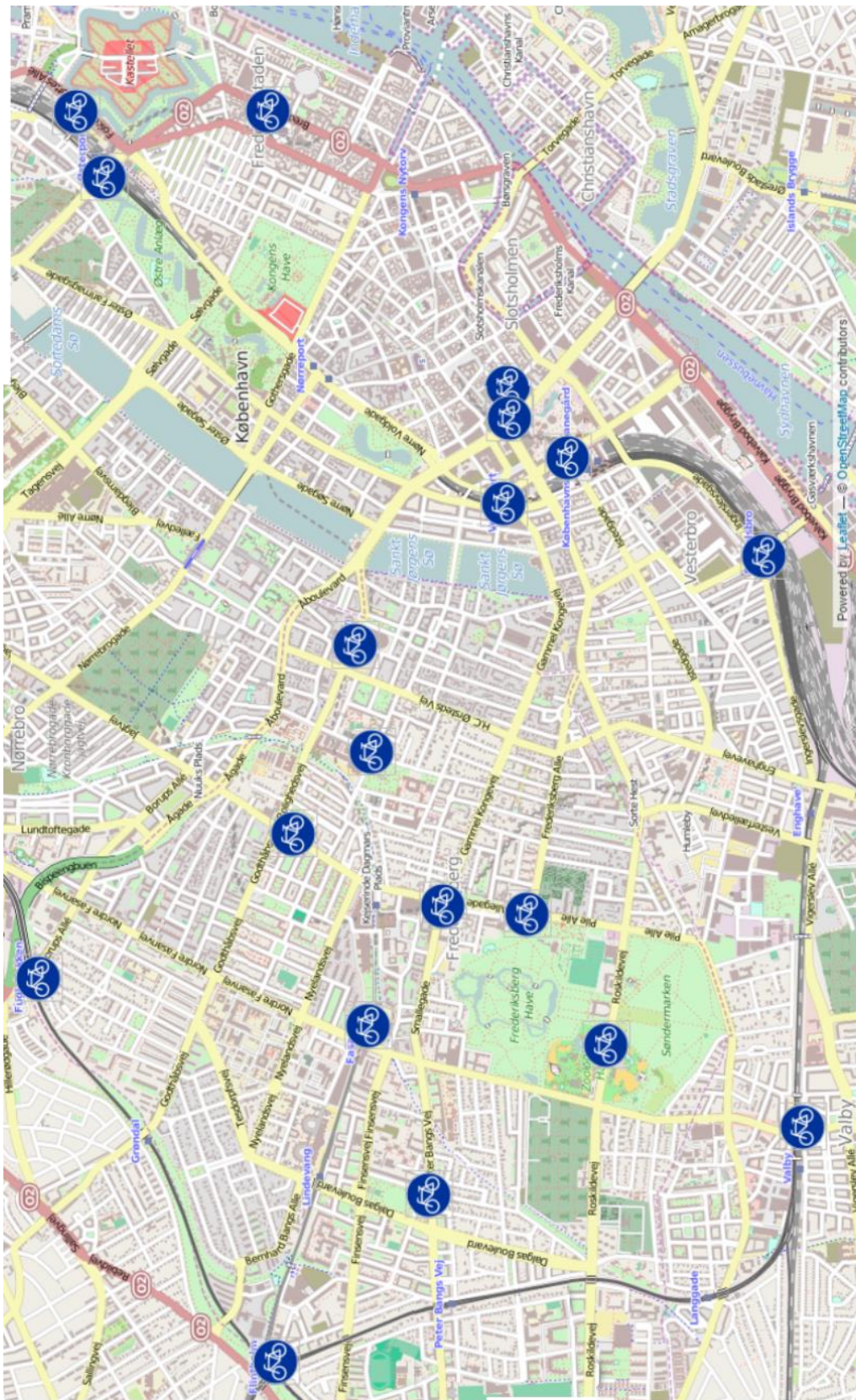
Appendix D: Focus Group Questions

1. What is your perception of electric bikes?
 - a. What do you like about them
 - b. What are your primary concerns about e-bikes
2. After seeing a picture of the e-bike, do you feel differently towards e-bikes?
3. If e-bike sharing was implemented, how do you think this would affect your life?
 - a. Would you travel more?
 - b. Would you go to places further away more often
4. Would you be willing to put down a 1500 RMB deposit for an e-bike rental?
5. How much would you be willing to pay per hour?
6. Do you consider public bicycles/ e-bike to be unsanitary? Would that stop you from using it?
7. Given the choice between e-bikes or bikes, which would you choose and why?
 - a. Cars, other public transportation
8. Any final comments about e-bikes?
 - a. Environmental
 - b. Safety
 - c. Ect.

Appendix E: Map of BiciMAD Stations



Appendix F: Map of Bycyclen Stations



Appendix G: English Translation of Instructions at Bike Sharing Station

GUIDANCE

1. Important notice:
 - Please check if the bicycle is in good condition before riding it.
 - Please check the rental condition on the self-service machine. The result should be “This card is not renting a bicycle/Bicycle returned”
 - The holder of the card should check the balance of the card in case of failure of renting bicycle because of low balance.
2. Renting and Returning Procedure:
 - Renting Procedure: Swipe the card on the locker; when green light turns from blink light to continue light with a beep, bicycle is unlocked, pull out the bicycle in 30 seconds.
 - Returning Procedure: Pull the bicycle into locker, when green light blink, keep the card on the locker; when green light turns to continue green light with a beep, the bicycle has been returned.
3. Abnormal condition:
 - Abnormal condition happens when user swipe rental card too fast. When this happens, Place your card on the self-services machine and press 4. Then card can return to normal condition.
4. Operation hour:
 - 6:00—21:00 (Renting time)
 - 7:00---22:00 (Returning time)
 - This station operate 24 hours
5. Rental fee:
 - Free within one hour; two hours for 1 RMB; three hours for 3 RMB; Over three hour, 3RMB for every additional one hour.

Service Hotline: 0571-85331122

Text Platform: 106573061122

Official WeChat: hz85331122

If anything abnormal on the system happen to you, you can text “Rental Card Number, station number and abnormal notice on the self-services machine screen” to Text Platform or Official WeChat.