

**Factors Influencing the Choice of Shared Bicycles and Electric Bicycles in Beijing – A  
Stated Preference Approach**

A Thesis Presented for the  
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## **Abstract**

Public bicycle systems, also known as bikeshare systems, are growing rapidly throughout the world, but nowhere more so than in China. At the same time the country's most rapidly growing mode of private transportation is the electric two wheeler, or e-bike. Despite the popularity of this mode and the similarity to conventional bicycles, there are currently no large scale public e-bike systems. To evaluate the adoption and use of an e-bikeshare system, this study employs a stated preference survey to investigate the factors influencing the choice to use a shared bike or e-bike system. An intercept survey queries 620 respondents in the four main urban districts of Beijing. The survey are entirely stated preference as opposed to the traditional revealed-stated preference hybrids that require estimation or measurement of unobserved factors and are subject to limited variation. The stated preference approach allowed surveyors to test a variety of environmental conditions that did not actually occur during the one month study period. The survey employs a main effects design to test environmental characteristics related to comfort, safety, and speed of travel. Survey data is used to build a multinomial logit choice model. The model indicates that the choice to use the shared bicycle is most sensitive to the respondent's original mode as well as trip distance and environmental conditions. The choice to use the shared electric bicycle is most influenced by socio-demographic characteristics such as income, education, and gender. The shared e-bike's insensitivity to distance can make it an attractive alternative to the shared bike. Concerning public transit, it is not clear what the relation with shared bikes will be, but it is clear the shared e-bike is attractive as a bus replacement mode. The study results suggest that a shared bike system in Beijing will mainly draw users from modes with low fuel consumption per passenger and from a variety of demographic groups. A shared e-bike system may be deployed in a focused manner by targeting specific user demographic groups and with specific transportation system goals such as relieving congested bus routes.

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## Ch. 1 – Introduction

Based on the percentage growth of fleet size and daily trips, public bikeshare systems are the world's fastest growing mode of public transportation [1]. The vast majority of that growth is taking place in China. China is also experiencing rapid growth of private electric bicycles (e-bike). Despite their popularity and similarity to conventional bicycles, there are no large scale shared e-bike systems and no known studies investigating the potential of such a system. Furthermore, the known body of bikeshare research has yet to produce behavior models to describe mode choice in a market that includes a bikeshare option. While we have a basic understanding of bikeshare users from surveys, there exists a gap in understanding when and why transportation users might adopt shared bicycle and e-bike systems, particularly related to environmental conditions, passenger taste heterogeneities and user characteristics. In an effort to close this gap, this study develops and implements a lightweight stated preference (SP) survey towards modeling mode switching in new bikeshare markets. The method was employed in a case study in Beijing that introduces shared bike and shared e-bike options.

This is a relevant and well-timed project given current trends in China and Beijing. A recent study estimates there are currently over 310,000 shared bikes in China and plans exist to increase that number to nearly a million [2]. A study from two years earlier estimated that there were less than 140,000 shared bikes throughout the entire world [3]. Although high profile systems in cities like Paris and Washington D.C. capture attention in the west, China has been the world's bikeshare growth leader since 2010. Bikesharing first emerged in 2005 in Beijing. The system employed second generation technology and was operated by several private rental companies. The fleet size was expanded to 5,000 to 10,000 bikes (sources vary) as part of the transportation reforms for the 2008 Olympics. By 2010 the system had collapsed. Research reports that the main reasons for the collapse were poor user experience, lack of a convenient network of rental stations and poor bicycle maintenance [4, 5]. Since then modern systems employing third generation electronic access technologies have flourished in other cities. At present date Shanghai, Hangzhou and Wuhan boast fleets of 20,000, 60,000 and 70,000 bikes respectively. In effort to implement the country's Transit Priority policy, Beijing has decided to deploy a new bikesharing system utilizing the third generation technology. The project opened in June 2012 with a 2,000 bike pilot in the Chaoyang and Dongcheng downtown districts and is reported to be expanding to 7,000 bikes [6].

In the realm of private transportation, e-bikes have been the fastest growing mode in China since the early 2000s. By the first years of that decade, virtually every large city in China had placed an embargo on permits for fuel burning two wheelers. This motivated exponential growth in annual e-bike sales to the point that they outpace motorcycle and automobile sales. Annual e-bike sales are on the scale of tens of millions and the current fleet size in China is estimated to be between 100 and 120 million. E-bikes offer increased mobility and access for citizens but come with concerns about safety and environmental impact. Research by Cherry et al. [7] looks at fatalities per vehicle kilometer traveled in two Chinese cities to conclude that e-bikes are somewhat more dangerous than bikes but much safer than cars. Weinert et al. [8] find that Chinese e-bike riders feel slightly safer than cyclists, but that conflicts in bike lanes are considered a problem. Environmental impacts are estimated by Cherry et al.

[9] in a lifecycle analysis comparing cars, buses, bicycles and e-bikes. The study finds that the bicycle outperforms the other modes in all energy and emissions categories. In general, the e-bike performs well in comparison with cars and buses except for lead emissions. In this category e-bikes are by far the emission leader due to their lead acid batteries. E-bikes have near zero emissions at point of use, but they are powered by an electric grid that is 75% coal fueled. Research by Ji et al. [10] estimates the health risk of station-to-wheel emissions of conventional and electric vehicles in China. The study finds that e-bikes generally perform very well, but create higher particulate matter exposure than gasoline burning cars and buses due to coal powered electricity production. Questions of environmental benefit aside, the e-bike is clearly a vital mode of transportation in China. A shared e-bike system may supplement Beijing's new bikeshare system to fulfill a different set of planning goals and user niches.

This paper seeks to identify the differences between the factors influencing the choice to switch to a shared bike or shared e-bike system. Who will use the system and for what kind of purposes? How do environmental factors related to comfort, air quality, and safety influence mode choice? How will these systems interact with public transit? What are the planning and system design implications? To answer these questions a SP intercept survey is conducted in the core urban districts of Beijing. It is expected that the use of shared two wheel systems will be sensitive to the local mix of user demographics, environmental conditions and existing transportation facilities. It is also expected that the difference in physical exertion required to operate bikes and e-bikes will manifest itself in different user behaviors. To this end the survey is designed to test variables of trip comfort, effort, environmental conditions and interactions with existing transportation. The data is used to build a multinomial logit (MNL) model that sheds light on the factors influencing the choice to switch to a shared bike or e-bike system. This research demonstrates that environmental conditions, population demographics and existing travel behaviors affect the adoption of bikeshare and e-bikeshare systems. These factors vary from city to city and as such, this research makes an important contribution in developing a replicable methodology for their evaluation. It is also the first known mode choice model developed for bikeshare or e-bikeshare.

The remainder of this thesis is broken into five chapters. First the existing body of bikeshare and e-bike literature is reviewed. This is followed by a methodology section covering survey design and administration. This section highlights several novel methodological contributions. The survey and modeling results are presented in the following two sections. The paper concludes with a discussion of the planning and design implications of the study results.

## **Ch. 2 – Literature Review**

There is a growing body of literature concerning bikeshare systems and e-bikes. The body of bikeshare research roughly falls into two categories: qualitative discussions of history, standards and guidelines and quantitative analysis of user surveys. Prominent qualitative studies by DeMaio [11] and Shaheen et al. [3] focus on defining bikesharing, describing its historical evolution and inventorying the world's bikesharing systems. There are four generations of bikesharing technology defined, with most modern systems considered third generation with distinctly marked bikes at docking stations with smart

electronic access control. Similar studies have identified distinctions in bikeshare network structures [12, 13]. The network structure seems to be a reaction to land use and the established transportation system, especially transit. Dense cities with a high level of transit use tend to favor bikeshare networks that are dispersed citywide. Less dense environments with branching transit tend to focus stations around transit facilities. These structures appear to influence the way bikesharing interacts with other transportation modes. Besides expository research, several reports in China and the West define physical and operational standards as well suggesting guidelines [1, 2, 5, 12, 14]. A common recommendation across all these reports is to integrate bikeshare with public transit through docking station location and the use of a common payment card. Bikeshare seems to be universally seen as an ideal complement to public transit.

In an effort to understand adoption, identify difference between users and non-users, and assess the impact on travel behavior, a number of online and intercept surveys of bikeshare users have been carried out in China and America [2, 5, 12, 15]. Shaheen et al. [12] investigates the existing bikesharing systems in North America. The authors employ a large user survey querying trip purpose, perceptions, and changes in travel behavior in the presence of bikeshare. The survey found that bikesharing draws users from all modes. When asked about how bikesharing impacts travel behavior, 30-50% of respondents reported decreasing the amount of trips for all modes except bicycle. Reductions in public transit, taxi and car use were reported by 39%, 46% and 40% of respondents respectively. Similar results were found in a study in China [15]. These studies suggest that bikeshare may be an effective means of decreasing motorization as well as the use of other modes, yet the results are sensitive to market density. In markets with high density and transit utilization, bikeshare reduced transit use more than in the lower density markets. In the market with the lowest density, respondents actually reported using transit more and had a larger decrease in driving. This suggests that bikesharing could serve as a transit connector in less dense markets where trip lengths are too long to be taken by bike. In such a market bikesharing can help make transit a more attractive alternative to driving.

The studies mentioned above ask questions based on perception, which may encourage over-reporting of mode shifting. Respondents were asked questions such as “do you drive less because of bikeshare?” Studies that focus on revealed trips, such that they ask users about actual trips, have all shown that bikeshare competes with transit, biking, and walking much more than with automobile options. A synthesis of research by Midgley [1] finds that in four major Western bikeshare systems, the large majority of bikeshare trips are being drawn from modes with lower fuel consumed per passenger compared with automobiles. In these cities 83% to 91% percent of bikeshare trips are replacing transit, walking or private bicycle trips. Only 7% to 13% of the bikeshare trips are replacing automobile trips. Studies in China have found similar results [5, 15]. These results suggest that in dense urban environments with high transit usage, bikeshare systems may not significantly reduce motorization rates but rather provide relief for congested transit modes and improve the accessibility range for those who would otherwise walk.

User surveys have revealed some similarities in demographics of users, but the impact of respondent heterogeneities on choice behavior is not well documented [5, 12, 15]. In both the West and China bikeshare users tend to be young with the large majority under the age of 40. Studies in Hangzhou

disagree on income range of most bikeshare users. Tang et al. [5] describe the users as white-collar low income workers. Shaheen et al. [15] find that Hangzhou bikeshare users are concentrated in the middle income brackets without significant correlation with gender and education. In North America the bikeshare users have very high college education rates and slightly higher incomes than local population [16].

Behavioral models have been employed to investigate the market adoption and mode choice regarding e-bikes. An early study by Chiu and Tzeng [17] investigates the market acceptance of e-bikes in Taiwan. The study employed a SP survey to build a multinomial logit (MNL) model to predict purchase choice from a set of three options: e-bike, lightweight motorcycle, and heavyweight motorcycle. The model results indicate that the decisions are not only driven by vehicle attributes, but also by respondent characteristics. These characteristics enter the model as both first-order variables as interactions with vehicle attributes, highlighting one of the advantages of using a choice model instead survey statistics: the MNL model makes it easier to identify significant interactions between variables. A RP survey by Cherry and Cervero [18] found statistically significant differences in education and income for the respondents who chose different modes. A MNL model revealed that these variables did not actually influence the decision response in a significant way. This is another example of the more nuanced interpretation of survey results that can be achieved by a choice model. A recent study by Cherry et al. [19] indicates that e-bike users tend to come from lower education and income brackets, a finding supported by their mixed logit model. It also reveals that different modes alternatives can be sensitive to different factors. For example, age is a highly significant variable for the car option but not the bicycle option. The known e-bike behavior models have not tested the influence of environmental factors like air quality, temperature and precipitation.

Other studies have investigated e-bike usage, adoption, and transportation impacts in China and Vietnam [8, 10, 20]. In general, these studies find that most e-bike trips are drawn from bicycles and buses. The studies also indicate that e-bikes draw 15% - 20% of trips from automobiles making them a better auto competitor than bikeshare. This difference in mode shift behavior is likely due to the increase in travel speed that e-bikes offer over bicycles. Studies have found that the e-bike offers a 25% faster trip speed, including stopped time [21, 22]. The e-bike mode shift behaviors and performance characteristics suggest that shared e-bike system will have a different impact on the transportation system than a bikeshare system. There has been very little exploration of the concept of a shared e-bike system and no such known studies in China [23].

The existing bikeshare studies demonstrate a strong tendency for bikeshare to compete with low fuel consumption per-passenger modes of transportation, though a potential to complement transit and replace automobile trips has also been demonstrated. The role of demographics in bikeshare user decision making is not well understood. Also the effects of environmental conditions are not explored thoroughly. Some of the studies asked questions about “bad weather” conditions, but none explored the impact temperature and air quality. Of all the known bikeshare studies, both in the West and China, none have created mode choice behavior models.

## Ch. 3 – Methodology

During the months of July and August, 2012, a mode choice survey was conducted in the four main urban districts of Beijing. The data were used to develop a multinomial logit model for mode choice. Three aspects of the survey make novel methodological contributions.

- It employs a pure SP design that uses an RPSP pivoting structure in order to capture inertia and provide a reference point.
- The survey queries trip links instead of trips, allowing for the assessment of bikeshare as both a complement and competitor to public transit.
- Affordable GPS technologies and publicly available data were used for quality control purposes in a data sparse environment.

This chapter is arranged into seven parts describing survey design, administration and study limitations.

### Ch. 3.1 – Survey Background

To the best of the author's knowledge, no existing studies have developed a discrete choice model that includes the bikeshare option. There have been several studies investigating e-bike market penetration and mode choice in China, Taiwan and Vietnam [17-19, 24].

Creating discrete choice models involves the analysis of preference data in the form of revealed preference (RP), stated preference (SP) or a combination of both (RPSP). Economists frequently prefer to use actual market consumption data, RP, due to its reflection of actual consumer choices. Models based on RP data will innately predict the current market equilibrium as well as capturing any technological or market constraints that are not directly observed. However RP studies suffer from two main drawbacks: a lack of attribute variation and the inability to model new products. Furthermore RP studies increase the burden on researchers by requiring them to observe or estimate all factors. For examples of RP studies of mode choice and freight demand see [16, 25]. Stated preference studies ameliorate the two main RP problems as well as offering researchers the advantage of full knowledge of all factors. Drawbacks of SP studies include response error and an inability to predict current market equilibrium. Examples of SP studies modeling new mode choice and changes in existing service include [13, 26, 27]. For a discussion of the tradeoffs between RP and SP methods see [28, 29].

In the 1990s RPSP methods evolved and gained favor in transportation studies. The original *data enrichment* methods combine data from separate RP and SP data sets. This enables sufficient attribute variation and the prediction of current market equilibrium. Since parameters are estimated on separate data sets, care must be taken in controlling scale factors in order to extract meaningful results. For discussion and examples see [28, 30, 31].

Advances in choice behavior research led to a new RPSP method that bases SP design off of RP responses. Known as *pivoting*, the survey first queries real world choice and alternative attributes. Enabled by computer aided personal interview (CAPI) technologies, a subsequent SP section is created with attribute levels based on those in the RP section. Pivoting creates reference points by which respondents can evaluate new options. It increases realism by giving the respondent a familiar context in which to evaluate the new alternatives. The RPSP method also makes it easy to capture inertia effects

by including an original choice variable [32, 33]. For examples and discussion of RPSP pivoting techniques see [34-36].

This study investigates a new travel mode not yet present in the market thus necessitates the use of a SP survey. The survey was designed to be conducted over a one month period with tight financial and labor constraints. To this end it was decided to eschew the popular computer-aided RPSP techniques for a paper-based SP intercept survey, see Appendix A.1 – Final Survey Design.

### **Ch. 3.2 – Survey Design**

The survey was designed to investigate the adoption of shared bike and shared e-bike systems in Beijing. Who would use such a system and for what kind of trips? How do environmental factors affect mode choice? What are the differences in the way users evaluate factors in choosing the shared bike and e-bike modes? Is the shared e-bike choice less sensitive to variables associated with physical effort and comfort such as distance, air quality and temperature?

A common format for the RPSP pivot surveys is to ask the respondent to fill out a travel diary in the RP section. The new alternatives are introduced in the SP section and the respondent is asked to choose between the original mode choice and one of the new options. The survey employed in this study follows a similar format to RPSP pivoting but predefines the environmental characteristics, making it a pure SP survey. See Figure 1. In Part One the respondent is asked to list all of the previous day's trip links under 10 km and to provide their distance, origin and destination. A trip link is defined as period of continuous travel by one mode. A single trip consists of one or more links. The distinction between trips and trip links is an important and novel aspect of this study to investigate the use of bikeshare for pieces of trips, particularly accessing transit. A full trip-based survey a priori frames transit and bikeshare as competition. By investigating trip links and using the origin and destination data it was possible to determine whether each link fed transit, was conducted on transit, or did not involve transit.

In Part Two the environmental characteristics, Table 1, are described and the respondent is asked to select a mode from a list of existing mode options (hereafter "original mode choice"). The respondent provides the estimated travel time and cost for the original mode choice. By first asking about the previous day's trip links, the respondent is primed to evaluate the given characteristics within a familiar context. The respondent can also employ reference point valuation. The original mode choice enters the MNL model as an inertia variable. Thus the survey makes an effort to capture the main advantages of RPSP pivoting in a pure SP design.

In Part Three the respondent is presented with the shared bike and shared e-bike options. The cost is given and the respondent is asked to estimate the travel time for the shared modes based on their own experience. It is assumed that bikesharing stations are present at the origin and destination, yielding zero access cost. If the respondent is unable to estimate travel time one is suggested based on the distance and the average reported travel speed [22]. Part Four asks the respondent to choose between the original mode choice and the two shared modes.

| Part-1                                                                                                                                                                                                    |                                                         | Part-2                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                          | Part-3                                                                                                                                                               |                                                                                                  | Part-4                                                                                                                                                                                                                                            |                         |                                 |                          |                                  |                                                                                              |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|---------------------------------|--------------------------|----------------------------------|----------------------------------------------------------------------------------------------|
| Think back to yesterday. Tell me about all the trip links you made that were less than 10 km.                                                                                                             |                                                         | Now suppose that it is <b>sunny</b> , 20 °C, the air quality is <b>bad</b> and congestion is <b>bad</b> . Also suppose, even though this may or may not be the reality for the trip you indicated, that bike lanes are available for <b>all</b> of the trip. If you have access to an automobile, assume your license plate is <b>restricted</b> . |                                                                                                                                          | Suppose for each of the above trips that you had the opportunity to instead use a shared bicycle or shared electric bike. The costs and travel times are as follows: |                                                                                                  | Now please consider the costs and travel times as well as all the attributes described in Part-2: it is <b>sunny</b> , 20 °C, the air quality is <b>bad</b> , congestion is <b>bad</b> and bicycle lanes are available for <b>all</b> of the trip |                         |                                 |                          |                                  |                                                                                              |
| Given these conditions, please indicate the transportation mode you would typically choose for each of the listed trips, and please indicate the approximate cost and travel time for each selected mode. | Trip Length<br>(approximate trip length to within 1 km) | Origin<br>1=home<br>2=work<br>3=school<br>4=store<br>5=restaurant<br>6=entertainment<br>7=transit facility<br>8=bus stop<br>9=other                                                                                                                                                                                                                | Destination<br>1=home<br>2=work<br>3=school<br>4=store<br>5=restaurant<br>6=entertainment<br>7=transit facility<br>8=bus stop<br>9=other | What Mode Would you Choose?<br>1=bus<br>2=subway<br>3=car (drive alone)<br>4=car (passenger)<br>5=bike<br>6=bike<br>7=walk<br>8=taxi<br>9=motorbike<br>10=other      | What would the approximate trip cost be?<br>(include fare, tolls, parking, and approximate fuel) | What would the approximate travel time be?<br>(元)                                                                                                                                                                                                 | Public bike cost<br>(元) | Public bike travel time<br>(分钟) | Public ebike cost<br>(元) | Public ebike travel time<br>(分钟) | Which would you choose for each trip?<br>1=same as Part-2<br>2=public bike<br>3=public ebike |
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Figure 1 – Example of Survey Mechanism

The environmental characteristics and cost attributes were generated using a main effects fractional factorial design in 18 treatments, yielding 18 unique surveys. Treatments were grouped into 56 blocks of 18 surveys in randomized order.

**Table 1 - Variable Levels**

|                                   | Factor Level |            |            |
|-----------------------------------|--------------|------------|------------|
|                                   | 1            | 2          | 3          |
| Precipitation                     | Sunny        | Light Rain | Heavy Rain |
| Temperature                       | -5 °C        | 15 °C      | 35 °C      |
| Air Quality                       | good         | medium     | bad        |
| Congestion                        | good         | medium     | bad        |
| Presence of Bike Lanes            | none         | half       | all        |
| Shared Bike Travel Cost [RMB]     | 0            | 1          | 2          |
| Shared E-bike Travel Cost [RMB]   | 0            | 1          | 2          |
| License Plate Number Restriction* | is           | is not     | NA         |

\*In Beijing automobiles are restricted from entering the core urban area (inside the 5<sup>th</sup> Ring Road) once every five days based on the last digit of the license plate.

The rest of the survey queried seven user demographic measures: age, gender, education level, education status, income level, environmental concern, and household access to vehicles.

### Ch. 3.2 – Training and Quality Control

A team of 15 students from Tsinghua University was hired to carry out the survey. Surveyors attended a one hour training session conducted in Mandarin. Feedback from the pilot surveys indicated many respondents were unclear about the concepts of a public bike system and trip links. During training surveyors were given explicit instruction on how to define these terms as part of their script. See Appendix C – Training Material for the training script. After orientation each member roll played in at least four scenarios, twice as surveyor and twice as respondent. Trainees were hesitant to engage in roll playing as the practice was unfamiliar to them. Afterwards most agreed that the technique had been helpful.

In the field surveyors took small gifts, souvenir key chains from Tsinghua University, to give to respondents as reward for filling out the survey. The gifts also served to assuage the surveyors' discomfort caused by inconveniencing strangers. This cultural consideration has been recommended by previous transportation researchers in China [37]. Other studies that used small gifts have mentioned a high rate of refusal to accept the gift among respondents. This was not the case for this study. In fact many respondents asked for multiple key chains to give to family and friends. This may be due to the prestige of Tsinghua University.

As a quality control measure, surveyors carried GPS loggers. The model employed was the Holux M-1200E, seen in Figure 2. Unlike many other GPS loggers, this unit is entirely configured through a software interface. This makes operation very simple for the end user who is only required to turn the device on. The free open source program BT747 was used to configure logging settings [38]. Time, latitude, longitude and horizontal dilution of precision (HDOP) were recorded. The HDOP field was used to filter bad readings.



Figure 2 - Holux M-1200E

Surveyors turned on the GPS unit at the start of each shift and returned the unit at the shift's end. The GPS tracks were checked nightly to make sure surveying was conducted in the appropriate areas and times. An example of the GPS track from a survey shift in Dongcheng District is seen in Figure 3. The track starts at Tsinghua University in the upper left corner. It disappears during the subway ride and reappears when the surveyor arrives at the assigned location. It should be noted that Chinese law makes it difficult to obtain high quality GIS information. Free open source panels were downloaded from OpenStreetMap.org and imported to ArcGIS using the ArcGIS Editor of OSM 2.0 [39, 40]. It should also be noted that foreign researchers must be very careful in their use of GPS technologies in China due to legal restrictions. It is not uncommon for illegal mapping to result in arrest [41]. To this end, only Chinese citizens handled the GPS units. Per the advice given by employees of the China Science and Technology Exchange Center, the principle researcher only worked with CSV files downloaded from the units, not the raw data.

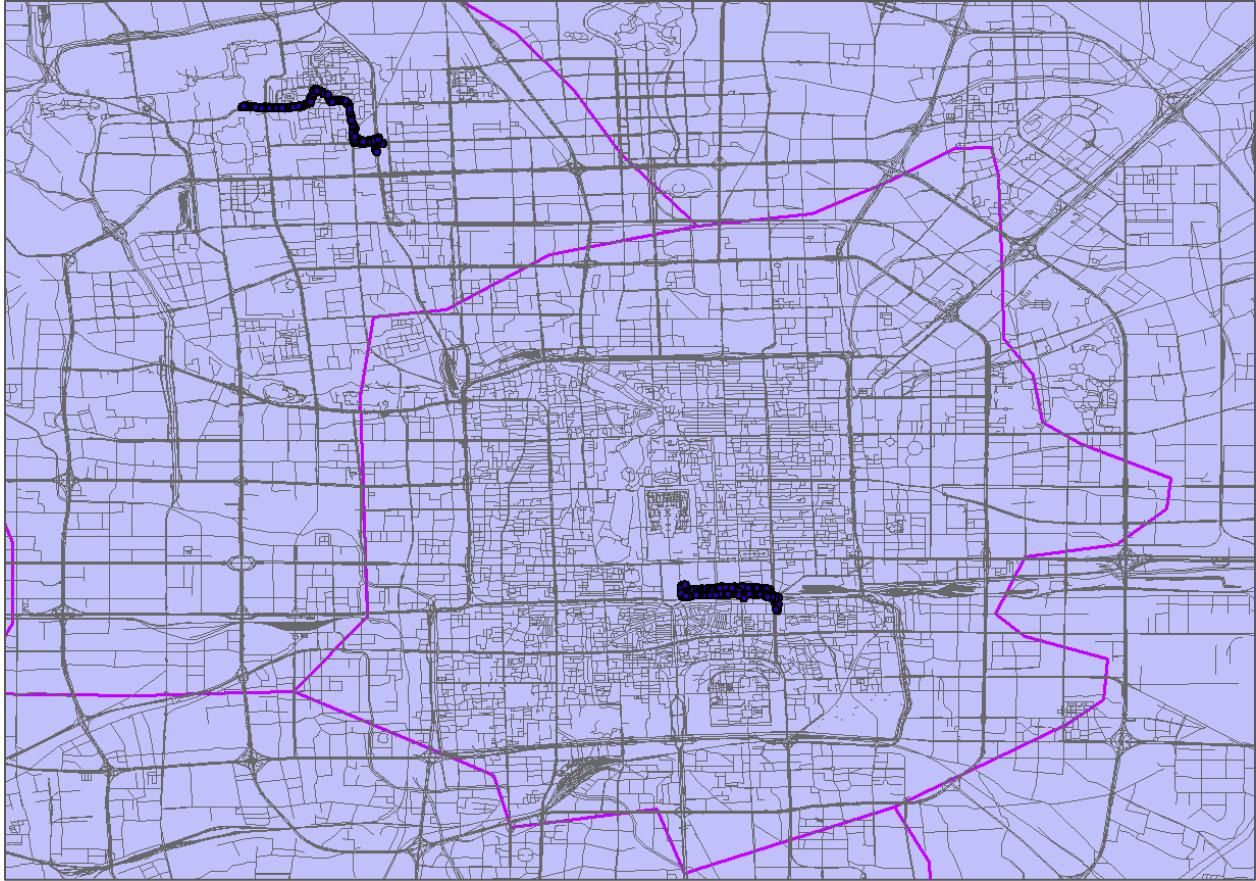


Figure 3- Example Survey Shift GPS Track

### Ch. 3.3 – Pilot Surveys and Design Revisions

The survey underwent three major design revisions based on feedback during five small pilot surveys. Each pilot survey collected 10-20 samples on the Tsinghua campus or in the surrounding area. After filling out the survey respondents were asked to answer four questions about the survey:

1. What attributes did you use in making your decision? Were there any you ignored?
2. What do you understand bicycle sharing to be?
3. Were you confused about any parts of the survey?
4. Do you have any suggestions for improving the survey?

See Appendices Appendix A.1 – Final Survey Design through Appendix A.4 – Third Survey Design for the evolution of the survey design.

Although many respondents were unfamiliar with bikeshare, enough did have experience with the systems in other cities, especially Hangzhou, that there were complaints about unreasonably high bikeshare prices. The decision was made to constrain the range of prices to approximate the existing systems so as to avoid causing cognitive dissidence in the respondents.

The most common point of confusion for respondents was the need to estimate travel times by bike and e-bike. To mitigate the problem, surveyors were given lookup tables taped to the back of their clipboards. See Appendix B - Travel Time Lookup Table. If a respondent was unable to estimate travel time, the lookup table was used to suggest a time based on the trip link distance. Some respondents reported confusion in estimate trip link distance. They were instructed to make their best guess. The hope is that trip distance error reporting was random and systematically biased.

### **Ch. 3.4 – Location Selection and Survey Scheduling**

Present day Beijing consists of 16 districts covering an area of 16,800 km<sup>2</sup>. Over 60% of residents live in the four core urban districts: Haidian, Chaoyang, Dongcheng and Xicheng [42]. In 2010 district lines were redrawn. Dongcheng annexed the former Chongwen District and Xicheng annexed the former Xuanwu District. Beijing residents and newspapers still frequently refer to the former districts as distinct entities. When this report refers to the six core urban districts, it includes Chongwen and Xuanwu as distinct districts.

These districts were selected as the most viable markets for shared two wheelers based on density, connectivity to transit, and commerce. Current bikeshare programs have been deployed in Dongcheng and Chaoyang Districts [43]. Each district was surveyed on multiple weekdays and at least one weekend day. At least seven groups of 18 surveys were collected in each district. Surveyors were scheduled to capture responses throughout the working day, from 9am to 9pm.

During each shift surveyors were assigned a specific one to three block area within walking distance of a subway station. During a shift a surveyor would sample users of one target mode. The blocks were assigned to give good access to users of the target modes of transportation.

### **Ch. 3.5 – Sampling Method**

The target population for the survey was adult users of the Beijing transportation system in core urban districts. During each shift a surveyor was responsible for completing one group of 18 surveys. During the shift the surveyor would question one of seven modes of transportation: walk, bike, e-bike, bus, subway, taxi, and private automobile. This was done in an effort capture any response bias latent in the mode of transportation being consumed at the time of surveying.

Surveyors would go to a location where people were actively engaged in using the mode of transportation to be sampled. The surveyor would pick an arbitrary marker, such as a line in the sidewalk. The surveyor would question the first user of the target mode to cross the marker. Other people would be ignored until the survey was completed.

### **Ch. 3.6 – Study Limitations**

The risk of response error in SP surveys increases with unfamiliarity with the given technology studied. In Beijing the population is very familiar with bicycles and e-bikes. The concept of a public system of these vehicles is however unfamiliar to many.

Selection bias is a problem inherent to intercept surveys. The response demographics discussed in the proceeding sections suggest that the sample is not representative of the total population.

However, accurate and detailed demographic data is not available for Beijing. It is unclear to how much the sample demographics differ from those of the areas surveyed. A future study with more resources should deploy surveyors in pairs. One person will conduct the survey while the other records refusal rates and estimates demographic data.

The bikeshare price range was constrained to reflect practices in other Chinese bikeshare systems. This led to insufficient variation to provoke a significant response. For this reason cost does not enter the MNL model.

As multiple observations were collected from single respondents, the assumption of identical and independent distribution (iid) of error terms is called into question. Further research should test the iid assumption employed in the MNL as well as exploring more robust models such as the mixed logit.

Despite these limitations it is believed that this survey is a valuable first step in evaluating the roll and usage of a shared bike and/or e-bike systems in Beijing. The model reveals clear differences in the decision making process people use to evaluate the shared bike and e-bike modes.

## **Ch. 4 – Survey Results**

The survey was conducted over a three weeks period in July and August 2012. A total of 623 surveys with 1,427 observations were collected. Many respondents declined to provide personal information about age, income or education. After removing samples with missing demographics, a total of 496 surveys and 1,188 observations were analyzed, averaging 2.40 observations per survey. Shared e-bikes and bikes were chosen in 15% and 10% of the observations respectively. The respondent demographics and their travel characteristics are presented in the next two sections.

### **Ch. 4.1 – Respondent Demographics**

The following tables present demographic data broken out by final mode choice. In Table 2 through Table 7, the percentages without parentheses describe the distribution of respondents within each sub-sample. The sub-samples are aggregated by final mode choice, as indicated by the column header. The values in parentheses show the percentage difference between respondents who switch to the given shared mode and those who maintain the original mode choice.

According to the 2010 National Population Census, the gender split in the case study districts is 52.5% male and 47.5% female. This is very close to the 52.2% and 47.8% split for Beijing as a whole. As seen in Table 2, the respondent sample has a much higher percentage of males. The census divides age into three groups with splits at 14 and 64 years old. According to the census, the over 65 group constitutes 10% of the population, indicating that the group is under sampled in this study [42]. However, demographics of people refusing to take the survey were not recorded, so it is not clear what the actual demographics of the study locations were. The data does suggest a strong negative reaction to the shared e-bike for respondents over 55. As a result it will be important to consider the possible non-linearities in the influence of age on mode choice in the MNL framework.

Table 2 – Mode Share by Respondent Age and Gender

| Total<br>N = 1188 | Mode Switchers |         |             |        | Chose Original<br>Mode |
|-------------------|----------------|---------|-------------|--------|------------------------|
|                   | Shared E-bike  |         | Shared Bike |        |                        |
|                   | N = 167        |         | N = 117     |        | N = 904                |
| Age               |                |         |             |        |                        |
| < 20              | 14%            | (8%)    | 11%         | -(15%) | 13%                    |
| 21 - 25           | 17%            | -(23%)  | 31%         | (41%)  | 22%                    |
| 26 - 30           | 19%            | -(17%)  | 18%         | -(22%) | 23%                    |
| 31 - 35           | 15%            | (7%)    | 9%          | -(36%) | 14%                    |
| 36 - 40           | 20%            | (122%)  | 6%          | -(33%) | 9%                     |
| 41 - 45           | 4%             | -(43%)  | 2%          | -(71%) | 7%                     |
| 46 - 50           | 9%             | (80%)   | 8%          | (60%)  | 5%                     |
| 51 - 55           | 1%             | (0%)    | 5%          | (400%) | 1%                     |
| 56 - 60           | 1%             | -(67%)  | 9%          | (200%) | 3%                     |
| 61 - 65           | 0%             | -(100%) | 1%          | (0%)   | 1%                     |
| > 65              | 0%             | -(100%) | 1%          | (0%)   | 1%                     |
| Gender            |                |         |             |        |                        |
| Male              | 66%            | (3%)    | 62%         | -(3%)  | 64%                    |
| Female            | 34%            | -(6%)   | 38%         | (6%)   | 36%                    |

\*Percentage of sample shown without parentheses. Percentage change from sample choosing original mode is shown in parentheses.

The data in Table 3 describes income, education, and household access to vehicles. These variables reflect social class heterogeneities. Based on previous studies and anecdotal evidence, it was expected that the shared modes would be favored by young, educated, middle income people with some level of environmental concern. It is not clear from this dataset that this is the case. Respondents who chose the shared e-bike do show large shifts to the lower income and lower education categories. Both shared modes are favored by active students.

Table 3 – Mode Share by Respondent Income, Education, and Household Vehicle Access

| Total<br>N = 1188                   | Mode Switchers |        |             |         | Choose Original<br>Mode |
|-------------------------------------|----------------|--------|-------------|---------|-------------------------|
|                                     | Shared E-bike  |        | Shared Bike |         |                         |
|                                     | N = 167        |        | N = 117     |         | N = 904                 |
| Income [RMB/month]                  |                |        |             |         |                         |
| <2,000                              | 29%            | (45%)  | 25%         | (25%)   | 20%                     |
| 2,000-6,000                         | 53%            | (2%)   | 53%         | (2%)    | 52%                     |
| 6,000-10,000                        | 16%            | -(20%) | 15%         | -(25%)  | 20%                     |
| 10,000-14,000                       | 1%             | -(80%) | 4%          | -(20%)  | 5%                      |
| 14,000-18,000                       | 1%             | (0%)   | 0%          | -(100%) | 1%                      |
| >18,000                             | 1%             | -(50%) | 3%          | (50%)   | 2%                      |
| Highest Level of Education Obtained |                |        |             |         |                         |
| Grade School                        | 13%            | (63%)  | 9%          | (13%)   | 8%                      |
| High School / Technical School      | 35%            | (35%)  | 22%         | -(15%)  | 26%                     |
| Undergraduate / Associates          | 47%            | -(19%) | 56%         | -(3%)   | 58%                     |
| Graduate                            | 5%             | -(38%) | 12%         | (50%)   | 8%                      |
| Student Status                      |                |        |             |         |                         |
| Enrolled                            | 18%            | (38%)  | 22%         | (69%)   | 13%                     |
| Not Enrolled                        | 82%            | -(6%)  | 78%         | -(10%)  | 87%                     |
| Environmental Concern               |                |        |             |         |                         |
| Very Concerned                      | 58%            | (29%)  | 53%         | (18%)   | 45%                     |
| Somewhat Concerned                  | 41%            | -(23%) | 44%         | -(17%)  | 53%                     |
| Not at all Concerned                | 1%             | -(50%) | 3%          | (50%)   | 2%                      |
| Average Household Vehicle Access    |                |        |             |         |                         |
| Bikes                               | 1.04           | (11%)  | 1.15        | (22%)   | 0.94                    |
| E-bikes                             | 0.47           | (7%)   | 0.42        | -(5%)   | 0.44                    |
| Automobiles                         | 0.53           | (8%)   | 0.53        | (8%)    | 0.49                    |

\*Percentage of sample shown without parentheses. Percentage difference from sample choosing original mode is shown in parentheses.

Table 4 presents the observed mode choice shares in each district. It is interesting to see the different behaviors in Chongwen and Dongcheng Districts as both were sampled near tourist attractions such as Tiananmen Square and the Temple of Heaven. In Chaoyang samples were collected near the central business district and near the popular Sanlitun shopping and entertainment center. Haidian is a geographically large district, but sampling focused on the areas populated by students of the district's many universities. In Xicheng and Xuanwu sampling was conducted in areas of commerce. The physical design and population of these districts have all shifted dramatically in the last decade. The lack of nuanced information about the local demographics and commercial activity inhibits interpretation of these results.

**Table 4 – Mode Share by District**

| Total<br>N = 1188 | Mode Switchers |        |             |        | Choose Original<br>Mode |
|-------------------|----------------|--------|-------------|--------|-------------------------|
|                   | Shared E-bike  |        | Shared Bike |        |                         |
|                   | N = 167        |        | N = 117     |        | N = 904                 |
| District Surveyed |                |        |             |        |                         |
| Chongwen**        | 3%             | -(73%) | 1%          | -(91%) | 11%                     |
| Dongcheng         | 28%            | (27%)  | 26%         | (18%)  | 22%                     |
| Chaoyang          | 14%            | -(18%) | 19%         | (12%)  | 17%                     |
| Haidian           | 5%             | -(38%) | 9%          | (13%)  | 8%                      |
| Xicheng           | 19%            | -(10%) | 15%         | -(29%) | 21%                     |
| Xuanwu**          | 32%            | (45%)  | 31%         | (41%)  | 22%                     |

\*Percentage of sample shown without parentheses. Percentage change from sample choosing original mode is shown in parentheses.

\*\* Chongwen and Xuanwu were annexed by Dongcheng and Xicheng in 2010.

## Ch. 4.2 – Respondent Travel Characteristics

This section compares the differences in travel characteristics of the respondents based on their mode choice. Table 5 presents the mode shift from original mode choice to each of the shared options. This table illustrates an important phenomenon, the distinction in behavior between respondents whose original mode choice was sheltered and those whose choice was not sheltered. The sheltered modes, Bus, Subway, Drive Alone and Taxi, are all under-represented in the sample of mode switchers. The unsheltered modes, highlighted in Table 5, show large shifts toward the shared modes. The data indicates that behavioral inertia plays a big part in the mode choice decision. A shared bike system will draw nearly half its users from the walking mode.

It should be noted that for the shared e-bike diverts a large percentage of its users from the bus. The MNL results presented later indicate the e-bike actually competes with the bus. Also of note is how much more the shared e-bike competes with automobiles. Shared e-bikes and shared bikes respectively draw 17% and 8% of their users from the automobile modes.

Table 5 – Mode Shift Distribution

| Total<br>N = 1188    | Mode Switchers |        |             |        | Choose Original<br>Mode |
|----------------------|----------------|--------|-------------|--------|-------------------------|
|                      | Shared E-bike  |        | Shared Bike |        |                         |
|                      | N = 167        |        | N = 117     |        | N = 904                 |
| Original Mode Choice |                |        |             |        |                         |
| Bus                  | 22%            | -(4%)  | 17%         | -(26%) | 23%                     |
| Subway               | 8%             | -(53%) | 3%          | -(82%) | 17%                     |
| Auto Solo            | 6%             | -(50%) | 3%          | -(75%) | 12%                     |
| Carpool              | 1%             | NA     | 3%          | NA     | 0%                      |
| Taxi                 | 10%            | -(17%) | 2%          | -(83%) | 12%                     |
| Private E-bike       | 15%            | (150%) | 6%          | (0%)   | 6%                      |
| Private Bike         | 11%            | (57%)  | 17%         | (143%) | 7%                      |
| Walk                 | 28%            | (22%)  | 49%         | (113%) | 23%                     |
| Motorcycle           | 0%             | NA     | 0%          | NA     | 0%                      |
| No Trip              | 0%             | NA     | 0%          | NA     | 0%                      |

The distribution of trip link distances is displayed in Table 6. Although respondents were instructed to only report trip links less than 10 km, many reported longer. Observations of trip links greater than 20 km were removed when creating the percentiles. The data clearly indicates that the shared e-bike is favored for longer trips than the shared bike. For the shared bike 40% of trips are 1 km whereas only 25% of the shared e-bike trips are under that length. At 10 km, the 85<sup>th</sup> percentile for the shared e-bike is twice as long as for the bike. These results support the hypothesis that shared e-bike users are willing to travel farther distances.

Table 6 – Trip Link Distance Percentiles

| Total<br>N = 1170 | Mode Switchers |             | Choose Original<br>Mode |
|-------------------|----------------|-------------|-------------------------|
|                   | Shared E-bike  | Shared Bike |                         |
|                   | N = 166        | N = 115     | N = 889                 |
| Percentiles [km]  |                |             |                         |
| 5%                | 0.2            | 0.5         | 0.5                     |
| 10%               | 0.4            | 0.5         | 0.6                     |
| 15%               | 0.5            | 0.8         | 1.0                     |
| 20%               | 1.0            | 1.0         | 1.0                     |
| 25%               | 1.0            | 1.0         | 2.0                     |
| 30%               | 1.5            | 1.0         | 2.0                     |
| 35%               | 2.0            | 1.0         | 3.0                     |
| 40%               | 2.0            | 1.0         | 3.0                     |
| 45%               | 3.0            | 1.5         | 4.0                     |
| 50%               | 4.0            | 1.5         | 5.0                     |
| 55%               | 4.8            | 2.0         | 6.0                     |
| 60%               | 5.0            | 2.0         | 7.0                     |
| 65%               | 5.0            | 2.9         | 8.0                     |
| 70%               | 6.0            | 3.0         | 8.0                     |
| 75%               | 8.0            | 3.0         | 10.0                    |
| 80%               | 8.0            | 4.0         | 10.0                    |
| 85%               | 10.0           | 5.0         | 10.0                    |
| 90%               | 10.0           | 7.0         | 10.0                    |
| 95%               | 10.0           | 10.0        | 15.0                    |
| 100%              | 20.0           | 20.0        | 20.0                    |

\*All trips greater than 20 km have been removed.

Table 7 presents the distribution of trip link origins and destinations. It is clear that respondents were biased towards reporting morning trip links since the percent originating at home is so much larger than the percent finishing at home. A relatively high percent of the mode switchers' original trip links started or finished at bus stops, again indicating the shared modes compete with bus transit. The data in these three tables indicate that shared bike and shared e-bike systems will be used differently. A shared e-bike system can be an effective tool for diverting passengers from medium to long length bus routes.

Table 7 – Respondent Mode Share by Origin and Destination

| Total<br>N = 1188 | Mode Switchers |         |             |         | Choose Original<br>Mode |
|-------------------|----------------|---------|-------------|---------|-------------------------|
|                   | Shared E-bike  |         | Shared Bike |         |                         |
|                   | N = 167        |         | N = 117     |         | N = 904                 |
| Origin            |                |         |             |         |                         |
| Home              | 45%            | -(20%)  | 58%         | (4%)    | 56%                     |
| Work              | 13%            | (18%)   | 3%          | -(73%)  | 11%                     |
| School            | 2%             | (0%)    | 3%          | (50%)   | 2%                      |
| Store             | 1%             | (0%)    | 0%          | -(100%) | 1%                      |
| Restaurant        | 0%             | NA      | 2%          | NA      | 0%                      |
| Entertainment     | 0%             | -(100%) | 1%          | (0%)    | 1%                      |
| Subway Station    | 13%            | (0%)    | 10%         | -(23%)  | 13%                     |
| Bus Stop          | 25%            | (67%)   | 18%         | (20%)   | 15%                     |
| Other             | 2%             | (0%)    | 5%          | (150%)  | 2%                      |
| Destination       |                |         |             |         |                         |
| Home              | 4%             | (33%)   | 3%          | (0%)    | 3%                      |
| Work              | 23%            | -(12%)  | 18%         | -(31%)  | 26%                     |
| School            | 3%             | (50%)   | 4%          | (100%)  | 2%                      |
| Store             | 4%             | -(43%)  | 7%          | (0%)    | 7%                      |
| Restaurant        | 1%             | -(67%)  | 3%          | (0%)    | 3%                      |
| Entertainment     | 8%             | -(27%)  | 13%         | (18%)   | 11%                     |
| Subway Station    | 16%            | -(6%)   | 14%         | -(18%)  | 17%                     |
| Bus Stop          | 31%            | (82%)   | 22%         | (29%)   | 17%                     |
| Other             | 11%            | -(27%)  | 16%         | (7%)    | 15%                     |

## Ch. 5 – Modeling Mode Shifts with a Multinomial Logit Model

### Ch. 5.1 – General Results

A MNL switching model was estimated using the survey data. The model predicts the likelihood of a respondent switching from the original mode choice to each of the two shared modes. Through the process of testing specifications, certain variables were removed either because of insignificant or troublesome behavior. The travel cost variable was removed for having the wrong sign and insignificant p-values. It is likely that the cost variable's behavior is due to insufficient variation. The shared mode costs were based on real world bikeshare prices and the maximum price, two RMB, was probably not high enough to provoke a strong reaction. The bike lane variable was supposed to act as a measure of safety but it failed to provoke a significant response. This may be explained by the fact that the survey did not distinguish between protected and unprotected bike lanes. The majority of Beijing streets have some sort of marked bike lane, but only a small percent have protected bike lanes. Some respondents commented that the bike lane variable was confusing since only freeways do not have bike lanes. Other variables, such as original mode choice and origin and destination were aggregated in ways to improve parameter significance and interpretation. Table 8 describes each of the 14 categories of variables.

**Table 8 – Variable Descriptions**

| <b>Variable</b>                              | <b>Description</b>                                                                                                                                                                                          |
|----------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Alternative Specific Constant                | Captures all unobserved factors.                                                                                                                                                                            |
| Age                                          | Age in years. Allows non-linear contribution of age to utility.                                                                                                                                             |
| Age Squared                                  |                                                                                                                                                                                                             |
| Air Quality Bad Indicator * Distance [km]    | Air Quality is a categorical indicator variable. It is interacted with distance to capture exposure.                                                                                                        |
| Air Quality Medium Indicator * Distance [km] |                                                                                                                                                                                                             |
| Air Quality Good Indicator * Distance [km]   |                                                                                                                                                                                                             |
| Congestion Indicator                         | Congestion is categorical indicator. It is equal to one if congestion is present.                                                                                                                           |
| Congestion Indicator * Female Indicator      |                                                                                                                                                                                                             |
| Distance [km]                                | Self-reported distance, in kilometers, of trip link.                                                                                                                                                        |
| Higher Education Indicator                   | Indicates if respondent has or is currently receiving college education                                                                                                                                     |
| Environmental Concern Indicator              | Indicates if concern is medium or high.                                                                                                                                                                     |
| Gender Female Indicator                      | Indicates if respondent was female.                                                                                                                                                                         |
| Income                                       | Respondent's income in 1,000 RMB/month.                                                                                                                                                                     |
| License Plate Restriction Indicator          | Indicates if respondent's hypothetical license plate number is restricted.                                                                                                                                  |
| Original Mode Sheltered Indicator            | Indicates whether original mode choice was or was not in a sheltered vehicle.                                                                                                                               |
| Original Mode Not Sheltered Indicator        |                                                                                                                                                                                                             |
| Heavy Rain Indicator                         | Categorical indicator of precipitation level.                                                                                                                                                               |
| Light Rain Indicator                         |                                                                                                                                                                                                             |
| No Rain Indicator                            |                                                                                                                                                                                                             |
| Temperature Cold Indicator * Distance        | Temperature is a categorical indicator that is interacted with trip link distance to capture exposure.                                                                                                      |
| Temperature Hot Indicator * Distance         |                                                                                                                                                                                                             |
| Temperature Comfortable Indicator * Distance |                                                                                                                                                                                                             |
| Original Trip Link by Bus                    | Indicates the trip link's relationship to transit. A transit feeder link either originated or terminated at a transit facility, but not both. These variables are based on the Origin and Destination data. |
| Original Trip Link was Transit Feeder        |                                                                                                                                                                                                             |
| Original Trip Link did not Involve Transit   |                                                                                                                                                                                                             |
| Original Trip Link by Subway                 |                                                                                                                                                                                                             |

The results of the MNL estimation are presented in Table 9. Original mode choice is the basis of comparison, meaning the parameters describe change in utility for switching to either shared mode relative to not switching. The two shared modes have very different magnitude of response to most of the variables. Only the alternative specific constants (ASC) and rain indicators have parameters for both modes that are significant below the 5% level. This indicates that the choices to use shared bike and shared e-bike are governed by different factors. The e-bikeshare ASC is more negative than the bikeshare ASC, indicating that the effect of all unobserved factors is more negative for the e-bike mode.

Table 9 -- MNL Estimation Results

| Variable                                     | Shared E-bike |         | Shared Bike |         |
|----------------------------------------------|---------------|---------|-------------|---------|
|                                              | Parameter     | p-value | Parameter   | p-value |
| Alternative Specific Constant                | -6.29         | 0       | -4.43       | 0       |
| Heavy Rain Indicator                         | Fixed         | Fixed   | Fixed       | Fixed   |
| Light Rain Indicator                         | 0.496         | 0.03    | 0.715       | 0.02    |
| No Rain Indicator                            | 1.15          | 0       | 1.01        | 0       |
| Original Mode Sheltered Indicator            | Fixed         | Fixed   | Fixed       | Fixed   |
| Original Mode Not Sheltered Indicator        | 0.368         | 0.12    | 1.12        | 0       |
| Air Quality Bad Indicator * Distance [km]    | Fixed         | Fixed   | Fixed       | Fixed   |
| Air Quality Medium Indicator * Distance [km] | 0.00856       | 0.77    | 0.175       | 0.01    |
| Air Quality Good Indicator * Distance [km]   | -0.0263       | 0.43    | 0.123       | 0.05    |
| Distance [km]                                | -0.0517       | 0.22    | -0.137      | 0.04    |
| License Plate Restriction Indicator          | -0.0762       | 0.68    | 0.418       | 0.06    |
| Temperature Cold Indicator * Distance        | -0.0394       | 0.26    | -0.0923     | 0.05    |
| Temperature Hot Indicator * Distance         | -0.0141       | 0.66    | -0.0902     | 0.23    |
| Temperature Comfortable Indicator * Distance | Fixed         | Fixed   | Fixed       | Fixed   |
| Higher Education Indicator                   | -0.679        | 0       | 0.207       | 0.43    |
| Environmental Concern Indicator              | 0.807         | 0       | 0.336       | 0.12    |
| Age                                          | 0.313         | 0       | 0.046       | 0.3     |
| Age Squared                                  | -0.0044       | 0       | -0.000528   | 0.32    |
| Congestion Indicator                         | -0.576        | 0.01    | 0.247       | 0.41    |
| Congestion Indicator * Female Indicator      | 0.793         | 0.06    | 0.502       | 0.3     |
| Gender Female Indicator                      | -0.779        | 0.02    | -0.291      | 0.49    |
| Income                                       | -0.128        | 0       | -0.0196     | 0.55    |
| Original Trip Link by Bus                    | 1.61          | 0       | 0.645       | 0.15    |
| Original Trip Link was Transit Feeder        | 0.329         | 0.12    | -0.0446     | 0.86    |
| Original Trip Link did not Involve Transit   | Fixed         | Fixed   | Fixed       | Fixed   |
| Original Trip Link by Subway                 | 0.629         | 0.14    | -1.2        | 0.24    |
| <b>No. Parameters Estimated</b>              | 42            |         |             |         |
| <b>Log Likelihood</b>                        | 1147.428      |         |             |         |
| <b>Adjust Rho-Square</b>                     | 0.407         |         |             |         |

## Ch. 5.2 – Discussion of Variable Categories

### Ch. 5.2.1 – Trip Characteristics

The e-bike fares better than the bike in regards to distance thus supporting the hypothesis that the e-bike has an advantage in variables related to physical effort. The response to distance has implications for planning. The average morning commute distance for automobile and buses in Beijing are 9.2 km and 9.6 km respectively [22]. At these distances half of the shared bike's ASC advantage would be erased by the e-bike's lower response to distance. This suggests the e-bikeshare system may better compete with those modes, depending on other variables.

The parameter for the Original Mode Not Sheltered Indicator is a measure of the influence of inertia on mode choice. Although the original mode choice is made in a stated preference environment, the choice describes a real trip link under conditions that are likely to have actually been experienced. Therefore it is reasonable to expect that effects of inertia of habit are captured by this variable. The parameter value is positive for both modes. It is much larger and highly significant for the bike. When implementing a shared two wheel system it will be important to understand the habits of the population. The shared bike will likely be the best option in an area where trip links are short and the population is in the habit of using unsheltered modes.

The four variables indicating the trip link's relation to transit are important for understanding how a shared system will impact transit. The e-bikeshare parameter for a trip link taken by bus is significant and positive, indicating the shared e-bike mode competes with the bus. None of the other transit interaction parameters are significant below 5%. Considering the transit parameters that are significant below the 15% level, both the shared modes compete with bus trip links. The shared e-bike also competes with subway links, though to a much lesser extent than with bus links. The shared e-bike can also complement transit as a feeder. However the feeder parameter is much smaller than the bus and transit link parameters. This indicates the shared e-bike is much more attractive as a competitor than as a complement to transit. The bikeshare feeder parameter is slightly negative and very insignificant, suggesting respondents did not have a meaningful response to the variable.

Taken together, the trip characteristic parameters suggest that a shared e-bike system will be much more effective than a shared bike system at drawing users away from buses. The long distances of bus trip links will be less onerous. The resistance from behavioral inertia to switching from a sheltered to unsheltered mode is much less severe. The transit interaction parameter indicates that other aspects of the mode make shared e-bikes a good competitor.

#### **Ch. 5.2.2 – Environmental Variables**

The shared bike is seen to be generally more sensitive to environmental conditions. Both modes however are sensitive to precipitation with respondents showing a strong preference for shifts away from the heavy rain condition. The magnitudes of response are similar for the two modes. It will be important to consider precipitation when forecasting demand and budgeting revenue. In 2011, Beijing received an inch or more of rain on approximately 115 days and two inches or more on 90 days [44]. Precipitation will have a large impact on demand in the city.

The air in Beijing frequently has very high concentration of particulate matter and it appears the population takes that into consideration when making travel choices. The air quality exposure parameters are positive and significant for the shared bike mode, though one would, however, expect good to be preferred to medium air quality. The e-bikeshare parameters are not significant. This may be explained by the fact that it takes more physical effort to operate the bicycle. Beijingers appear to be conscious of increased exposure due to breathing harder when physically laboring.

The reaction to temperature was also measured in terms of exposure. Even though temperature was presented to respondents as a Celsius measurement, it is treated as a categorical variable. That is

because respondents were only offered one of three temperatures, two of which were either uncomfortably hot or cold. The only parameter significant below 5% is the bikeshare response to the cold condition. In general the bikeshare parameters were more negative and more significant than the e-bikeshare parameters. Beijing experiences a large range of temperatures throughout the year. In 2011 approximately a third of the year's days could be considered to have experienced temperatures that were uncomfortably hot or cold. That year there were 41 days with a high temperature of 30°C or above and 79 days with low of 5°C or below. As with precipitation, the temperature should be considered when forecasting demand and revenue, especially for the bikeshare mode.

Congestion and license plate restriction enter the model as measures of the transportation environment. The congestion parameters are only significant for the shared e-bike. The issue of safety may be responsible for negative sign of the Congestion Indicator parameter. However it would seem odd that women prefer the congested condition. There is no basis for thinking that Beijing women prefer risk to men. One explanation may be found in previous research that shows that Chinese women feel safer crossing the street on e-bikes [45]. Alternatively, it may be that the congestion variable is confounded with transit crowdedness since surveyors explained congestion in terms of peak commute hours. Perhaps women prefer the e-bike to avoid the close physical contact that occurs on Beijing transit during peak hours. The parameter License Plate Restriction Indicator measures the response to having the respondent's theoretical license plate restricted for the day. This makes the shared bike a more attractive option but does not illicit a significant response for the e-bike.

### **Ch. 5.2.3 – Demographic Variables**

The shared e-bike is much more sensitive to demographic characteristics. It is alone in its significant response to education, income, environmental concern, age, and gender. The Higher Education and Income parameters are negative. This may be due to social class taste differences. The most visible e-bikes in Beijing are tools of blue collar work such as fast food delivery and cargo transport. The Environmental Concern parameter however is positive. Perhaps this is an effect of marketing that promotes electric vehicles as a “green” mode choice. Age contributes to utility in a concave parabolic manner. The contribution is maximized at 36 years and becomes negative beyond 72 years. Two conditions may explain this behavior. First, the e-bike is a relatively new mode choice and may seem more “natural” to younger generations. Older generations grew up in an era where cycling was the dominant mode throughout China. For them there is strong behavioral inertia motivating the choice to use a standard bicycle. Second, e-bikes are seen as unsafe and the elderly may be more concerned about crashing. The gender parameter indicates that women have distaste for the shared e-bike when considering all unobserved factors. The shared bike gender parameter is not significant.

## **Ch.6 – Conclusion**

This study suggests that shared two-wheelers can be a viable mode of public transportation in Beijing. This is evidenced by the 24% of observations that chose to switch modes and the variables that increase the attractiveness of the shared modes: good weather, inertia, and bus replacement. The MNL model indicates distinct differences in the factors influencing the decision to use the shared bike and

shared e-bike modes. The shared bike choice is mostly influenced by distance, environmental conditions and the user's habitual mode choices. The shared e-bike choice is more a function of taste heterogeneities. Variables of social class, age, gender and environmental concern most influence the e-bikeshare choice. In short, shared bicycle users are more likely to be traveling a short distance on a clear weather day and be from a range of age and demographic groups, while shared e-bike users are more likely to be young blue collar males concerned about the environment traveling medium distances. Both modes are very sensitive to rain and, in general, those originally traveling on a sheltered mode are typically reluctant to switch to the unsheltered shared bike modes.

The modeling results have several implications for planning and bikeshare system design. Both shared modes will draw more users from walking, biking and transit than from automobiles. This is evidenced by the survey statistics and the influential MNL inertia variable indicating if the original mode choice was sheltered. The transit interaction variable parameters suggest that both modes, especially the shared e-bike, will compete with public transit, especially buses.

What does this study suggest about the design of shared bike system in Beijing? Such a system may be best used to fortify sustainable transportation in the dense urban cores of Beijing. It will likely not be very effective in drawing people away from automobiles. By improving the cycling experience and range of accessibility for pedestrians, it may help curb increasing motorization. Bikeshare is likely to draw most of its users, who are sensitive to distance, from walking and biking modes. This suggests the system should be deployed in dense networks in areas with a high frequency of short trips. Docking stations should be diffused throughout the target area, rather than being clustered around transit. This would lower access and travel distances by placing stations closer to trip ends rather than transit facilities. Operators and planners must be aware of user sensitivity to air quality, temperature and precipitation. System inactivity due to environmental conditions must be considered when forecasting and budgeting.

The demand for a shared e-bike system will be highly sensitive to population demographics and as such should be deployed in areas where young blue collar males have a significant presence. This not only includes housing, but also employment centers. A shared e-bike system can be very effective in relieving some of the oversubscribed bus lines in Beijing. During peak hours it is not uncommon to see lines of hundreds of people at bus stops. Strategically located e-bikeshare systems could improve level of service on public buses and help curtail the rate of motorization. Such a system may help solve some of the problems introduced by the suburbanization of Chinese cities. One study has shown that residents who relocated to Beijing's outer districts experienced decreased resource access, increased driving rates and a 30% longer average commute [8]. Various measurement methods show the average trip speed of the e-bike offers a roughly 25% improvement over the standard bicycle [6, 21]. The MNL results indicate that users are much less sensitive to distance with the shared e-bike than with the shared bike. As such, a dispersed network of e-bikeshare stations clustered around bus stops in the outer districts of Beijing could help improve access, lower driving rates and relieve transit.

There are many opportunities for improving bike share behavioral modeling. Pricing strategies can play an important role in optimal system operation. A future study should explore much wider cost

variation in order to provoke significant response in the model. A more in depth exploration of the role of safety in mode choice is necessary. Finally, bikeshare offers a very intuitive and low cost solution to last mile transit connectivity problems, but the results of this survey indicate it will act more as a competitor. The intercept survey method severely limits the amount of respondent education that can take place. A recruitment based household survey could focus more on the transit connectivity issue and ensure the respondents understand the concept of trip links.

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## Appendices

## Appendix A – Survey Designs

### Appendix A.1 – Final Survey Design

Example of front side, English translation.

| 公共自行车交通所出行交通方式选择调查                                                                                                                                                                                        |                                                                                                                                                       |                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                                                                                                 |                                                                                                                                                                      |                                            |                                                                                                                                                                                                                                                   |                              |                       |                               |                                                                                                               |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------|-----------------------|-------------------------------|---------------------------------------------------------------------------------------------------------------|
| Part-1                                                                                                                                                                                                    |                                                                                                                                                       | Part-2                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                                                                                 | Part-3                                                                                                                                                               |                                            | Part-4                                                                                                                                                                                                                                            |                              |                       |                               |                                                                                                               |
| Think back to yesterday. Tell me about all the trip links you made that were less than 10 km.                                                                                                             |                                                                                                                                                       | Now suppose that it is <b>sunny</b> , 20 °C, the air quality is <b>bad</b> and congestion is <b>bad</b> . Also suppose, even though this may or may not be the reality for the trip you indicated, that bike lanes are available for <b>all</b> of the trip. If you have access to an automobile, assume your license plate is <b>restricted</b> . |                                                                                                                                                                                                 | Suppose for each of the above trips that you had the opportunity to instead use a shared bicycle or shared electric bike. The costs and travel times are as follows: |                                            | Now please consider the costs and travel times as well as all the attributes described in Part-2: it is <b>sunny</b> , 20 °C, the air quality is <b>bad</b> , congestion is <b>bad</b> and bicycle lanes are available for <b>all</b> of the trip |                              |                       |                               |                                                                                                               |
| Given these conditions, please indicate the transportation mode you would typically choose for each of the listed trips, and please indicate the approximate cost and travel time for each selected mode. |                                                                                                                                                       |                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                                                                                                 |                                                                                                                                                                      |                                            |                                                                                                                                                                                                                                                   |                              |                       |                               |                                                                                                               |
| Trip Length<br>(approximate trip length to within 1 km)                                                                                                                                                   | Origin<br>1 = home<br>2 = work<br>3 = school<br>4 = store<br>5 = restaurant<br>6 = entertainment<br>7 = transit facility<br>8 = bus stop<br>9 = other | Destination<br>1 = home<br>2 = work<br>3 = school<br>4 = store<br>5 = restaurant<br>6 = entertainment<br>7 = transit facility<br>8 = bus stop<br>9 = other                                                                                                                                                                                         | What Mode Would you Choose?<br>1 = bus<br>2 = subway<br>3 = car (drive alone)<br>4 = car (passenger)<br>5 = <del>ebike</del><br>6 = bike<br>7 = walk<br>8 = taxi<br>9 = motorbike<br>10 = other | What would the approximate trip cost be? (include fare, tolls, parking, and approximate fuel)                                                                        | What would the approximate travel time be? | Public bike cost (元)                                                                                                                                                                                                                              | Public bike travel time (分钟) | Public ebike cost (元) | Public ebike travel time (分钟) | Which would you choose for each trip?<br>1 = same as Part-2<br>2 = public bike<br>3 = <del>public ebike</del> |
|                                                                                                                                                                                                           |                                                                                                                                                       |                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                                                                                                 |                                                                                                                                                                      |                                            | 1                                                                                                                                                                                                                                                 |                              | 2                     |                               |                                                                                                               |
|                                                                                                                                                                                                           |                                                                                                                                                       |                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                                                                                                 |                                                                                                                                                                      |                                            | 1                                                                                                                                                                                                                                                 |                              | 2                     |                               |                                                                                                               |
|                                                                                                                                                                                                           |                                                                                                                                                       |                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                                                                                                 |                                                                                                                                                                      |                                            | 1                                                                                                                                                                                                                                                 |                              | 2                     |                               |                                                                                                               |
|                                                                                                                                                                                                           |                                                                                                                                                       |                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                                                                                                 |                                                                                                                                                                      |                                            | 1                                                                                                                                                                                                                                                 |                              | 2                     |                               |                                                                                                               |
|                                                                                                                                                                                                           |                                                                                                                                                       |                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                                                                                                 |                                                                                                                                                                      |                                            | 1                                                                                                                                                                                                                                                 |                              | 2                     |                               |                                                                                                               |
|                                                                                                                                                                                                           |                                                                                                                                                       |                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                                                                                                 |                                                                                                                                                                      |                                            | 1                                                                                                                                                                                                                                                 |                              | 2                     |                               |                                                                                                               |
|                                                                                                                                                                                                           |                                                                                                                                                       |                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                                                                                                 |                                                                                                                                                                      |                                            | 1                                                                                                                                                                                                                                                 |                              | 2                     |                               |                                                                                                               |

清华大学

北京市公共自行车租赁系统调查

问卷版本：1.2

| 第一部分                                                                | 第二部分                                                                                                                         | 第三部分                                                                            | 第四部分                                                                                                   |                                 |              |         |         |         |         |                                                               |
|---------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------|---------------------------------|--------------|---------|---------|---------|---------|---------------------------------------------------------------|
| 请回忆一下您昨天的出行，填在下面的空行处，出行距离在 10 公里以内。<br>请给出您完整的连续出行信息，如从家到地铁站之间的步行等。 | 假设昨天您的出行条件是：<br>天气晴：<br>气温-5°C：<br>空气质量中：<br>交通拥堵情况中：<br>全程有自行车道。<br>(空气质量情况和交通拥堵情况都为“好、中、差”三个等级。)<br>若您拥有私家车，假设您今天处于尾号限行状态。 | 假设您每次出门都可以使用公共自行车或公共电动车，<br>花费和耗时如下：                                            | 请考虑花费和耗时，以及第二部分中的出行条件：<br>天气晴：<br>气温-5°C：<br>空气质量中：<br>交通拥堵情况中：<br>全程有自行车道：<br>尾号限行。                   |                                 |              |         |         |         |         |                                                               |
|                                                                     | 请对每次行程分别选择您的出行方式并估计大概的花费和耗时。                                                                                                 |                                                                                 |                                                                                                        |                                 |              |         |         |         |         |                                                               |
| 出行距离<br>(尽量精确到 1km)                                                 | 起点<br>1=家<br>2=单位<br>3=学校<br>4=商店<br>5=饭店<br>6=娱乐场所<br>7=地铁站<br>8=公共汽车站<br>9=其他                                              | 终点<br>1=家<br>2=单位<br>3=学校<br>4=商店<br>5=饭店<br>6=娱乐场所<br>7=地铁站<br>8=公共汽车站<br>9=其他 | 您选哪种交通方式?<br>1=公共汽车<br>2=地铁<br>3=自驾私家车<br>4=搭乘私家车<br>5=电动车<br>6=自行车<br>7=步行<br>8=出租车<br>9=摩托车<br>10=其他 | 这样出门大概花多少钱? (考虑票价、通行费、停车费、燃油费等) | 这样出门大概花多少时间? | 公共自行车费用 | 公共自行车耗时 | 公共电动车费用 | 公共电动车耗时 | 在这样的条件下，您会选择公共自行车或公共电动车吗?<br>1=不会<br>2=会选择公共自行车<br>3=会选择公共电动车 |
|                                                                     |                                                                                                                              |                                                                                 |                                                                                                        | (元)                             | (分钟)         | (元)     | (分钟)    | (元)     | (分钟)    |                                                               |
|                                                                     |                                                                                                                              |                                                                                 |                                                                                                        |                                 |              | 2       |         | 1       |         |                                                               |
|                                                                     |                                                                                                                              |                                                                                 |                                                                                                        |                                 |              | 2       |         | 1       |         |                                                               |
|                                                                     |                                                                                                                              |                                                                                 |                                                                                                        |                                 |              | 2       |         | 1       |         |                                                               |
|                                                                     |                                                                                                                              |                                                                                 |                                                                                                        |                                 |              | 2       |         | 1       |         |                                                               |
|                                                                     |                                                                                                                              |                                                                                 |                                                                                                        |                                 |              | 2       |         | 1       |         |                                                               |
|                                                                     |                                                                                                                              |                                                                                 |                                                                                                        |                                 |              | 2       |         | 1       |         |                                                               |
|                                                                     |                                                                                                                              |                                                                                 |                                                                                                        |                                 |              | 2       |         | 1       |         |                                                               |
|                                                                     |                                                                                                                              |                                                                                 |                                                                                                        |                                 |              | 2       |         | 1       |         |                                                               |
|                                                                     |                                                                                                                              |                                                                                 |                                                                                                        |                                 |              | 2       |         | 1       |         |                                                               |

清华大学交通实验室

北京市公共自行车租赁系统调查

个人信息:

1) 年龄

20 岁及以下

21 至 25 岁

26 至 30 岁

31 至 35 岁

36 至 40 岁

41 至 46 岁

46 至 50 岁

51 至 55 岁

56 至 60 岁

61 至 65 岁

66 岁及以上

2) 性别

男

女

3) 受教育程度

小学或初中

中专或高中

大专或本科

研究生

4) 个人月收入

2,000元以下

2,000元至6,000元

6,000元至10,000元

10,000元至14,000元

14,000元至18,000元

18,000元以上

5) 是否在校学生

是

否

6) 是否关心周边环境质量?

非常关心

一般关心

毫不关心

7) 您家中有多少辆下列交通工具? (请填写数字)

( 辆) 自行车

( 辆) 电动自行车

( 辆) 汽车

保密性声明

此次调查是完全匿名的，您所提供的信息将不会被用于确认您的身份。

本次调研结束，感谢您的配合！

以下部分由调查人员完成

调查员

日期时间

回答者出行方式

调查地点

清华大学交通管理室

32

## Appendix A.2 – First Survey Design

### Part I – Transportation Choices

For each of the three trips described below, please choose one vehicle option for making the trip. Only choose a vehicle option you currently have access to or plan to have access to in the near future.

The air quality and traffic congestion are each divided into three levels: **good**, **fair** and **bad**. Four weather conditions are possible: **sunny**, **cloudy**, **raining** and **snowing**.

1) You need to make a **1.5 km** trip. It is **sunny**, **25 °C**, the air quality is **bad** and congestion is **bad**. Bicycle lanes are available for **half** of the trip. Which of the following transportation options would you choose to make this trip?

| Choose One | Mode                    | Travel Time (minutes) | Cost    |
|------------|-------------------------|-----------------------|---------|
|            | Walk                    | 20                    | 0       |
|            | Personal Bicycle        | 9                     | 0       |
|            | Personal Electric Bike  | 6                     | 0       |
|            | Personal Car            | 10                    | 15 yuan |
|            | Subway                  | 4                     | 2 yuan  |
|            | Bus                     | 4                     | 4 jiao  |
|            | Shared Electric Bicycle | 9                     | 1 yuan  |
|            | Shared Standard Bicycle | 10                    | 1 yuan  |
|            | Taxi                    | 10                    | 10 yuan |
|            | No Trip                 | 0                     | 0       |

2) You need to make a **2 km** trip. It is **sunny**, **35 °C**, the air quality is **very bad** and congestion is **good**. Bicycle lanes are available for **none** of the trip. Which of the following transportation options would you choose to make this trip?

| Choose One | Mode                    | Travel Time (minutes) | Cost    |
|------------|-------------------------|-----------------------|---------|
|            | Walk                    | 27                    | 0       |
|            | Personal Bicycle        | 8                     | 0       |
|            | Personal Electric Bike  | 6                     | 0       |
|            | Personal Car            | 3                     | 16 yuan |
|            | Subway                  | 5                     | 2 yuan  |
|            | Bus                     | 4                     | 4 jiao  |
|            | Shared Electric Bicycle | 6                     | 1 yuan  |
|            | Shared Standard Bicycle | 6                     | 1 yuan  |
|            | Taxi                    | 3                     | 10 yuan |
|            | No Trip                 | 0                     | 0       |

3) You need to make a **1.5 km** trip. It is **raining**, **20 °C**, and the air quality is rated **good** and the congestion is **fair**. Bicycle lanes are available for **all** of the trip. Which of the following transportation options would you choose to make this trip?

| Choose One | Mode                    | Travel Time (minutes) | Cost    |
|------------|-------------------------|-----------------------|---------|
|            | Walk                    | 20                    | 0       |
|            | Personal Bicycle        | 8                     | 0       |
|            | Personal Electric Bike  | 6                     | 0       |
|            | Personal Car            | 3                     | 15 yuan |
|            | Subway                  | 4                     | 2 yuan  |
|            | Bus                     | 4                     | 4 jiao  |
|            | Shared Electric Bicycle | 6                     | 1 yuan  |
|            | Shared Standard Bicycle | 8                     | 1 yuan  |
|            | Taxi                    | 4                     | 10 yuan |
|            | No Trip                 | 3                     | 0       |

## Part II – Demographics Information

### 1) Age

- |                                        |                                      |
|----------------------------------------|--------------------------------------|
| <input type="checkbox"/> 20 or younger | <input type="checkbox"/> 26 to 50    |
| <input type="checkbox"/> 20 to 25      | <input type="checkbox"/> 51 to 55    |
| <input type="checkbox"/> 26 to 30      | <input type="checkbox"/> 56 to 60    |
| <input type="checkbox"/> 31 to 35      | <input type="checkbox"/> 61 to 65    |
| <input type="checkbox"/> 36 to 40      | <input type="checkbox"/> 66 or older |
| <input type="checkbox"/> 41 to 45      |                                      |



### 2) Gender

- ☐ Male  
☐ Female

### 3) Highest level of education attained

- ☐ Grade school  
☐ High school diploma  
☐ Undergraduate degree  
☐ Graduate degree



### 4) Personal monthly income

- ☐ below 2,000 RMB  
☐ 2,000 RMB to 6,000 RMB  
☐ 6,000 RMB to 10,000 RMB  
☐ 10,000 RMB to 14,000 RMB  
☐ 14,000 RMB to 18,000 RMB  
☐ above 18,000 RMB

### 5) Mark how many of each vehicle are available to you in your household:

- ☐ bicycle  
☐ electric bicycle  
☐ car

### 6) Are you currently enrolled as a student?

- ☐ Yes  
☐ No

### 7) How concerned are you about the quality of the environment?

- ☐ Very concerned  
☐ Somewhat concerned  
☐ Not concerned at all

### Statement of Confidentiality

This survey is completely anonymous. The information you provide cannot be used to identify you.

---

### For Staff to Fill Out

- Surveyor ID \_\_\_\_\_
- Time and Date \_\_\_\_\_
- Mode \_\_\_\_\_
- Location \_\_\_\_\_

### Appendix A.3 – Second Survey Design

#### Transportation Choices

**Part I.** For each of the distances below, indicate a trip of that length that you make frequently.

| Trip | Distance     | Origin | Destination | Purpose |
|------|--------------|--------|-------------|---------|
| 1    | 0 – 1.50 km  |        |             |         |
| 2    | 1.5 – 2.5 km |        |             |         |
| 3    | 2.5 – 4 km   |        |             |         |

#### Part II.

We describe five conditions for making a trip: weather, temperature, air quality, traffic congestion and the presence of bicycle lanes. Air quality and traffic congestion have one of three levels: **good**, **medium**, and **bad**.

Now suppose that it is **sunny**, **20 °C**, the air quality is **bad** and congestion is **bad**. Also suppose, even though this may or may not be the reality for the trip you indicated, that bike lanes are available for **all** of the trip.

Given these conditions, please indicate the transportation mode you would typically choose for each of the above trips, and please indicate the approximate cost and travel time for each selected mode.

| Trip | Mode          | Cost    | Time |
|------|---------------|---------|------|
| 1    | Walk          | Car     |      |
|      | Bicycle       | Subway  |      |
|      | Electric Bike | Bus     |      |
|      | Taxi          | No Trip |      |
| 2    | Walk          | Car     |      |
|      | Bicycle       | Subway  |      |
|      | Electric Bike | Bus     |      |
|      | Taxi          | No Trip |      |
| 3    | Walk          | Car     |      |
|      | Bicycle       | Subway  |      |
|      | Electric Bike | Bus     |      |
|      | Taxi          | No Trip |      |

#### Part III

Regardless of your answer to Part II, please indicate how much time it would take you to make those trips using a regular bike and an electric bike.

|               | Trip 1 | Trip 2 | Trip 3 |
|---------------|--------|--------|--------|
| Bicycle       |        |        |        |
| Electric Bike |        |        |        |

**Part IV.** Suppose for each of the above trips that you had the opportunity to instead use a shared bicycle or shared electric bike. The costs are as follows:

|      | Shared Bicycle | Shared Electric Bike |
|------|----------------|----------------------|
| Cost | <b>1 yuan</b>  | <b>2 yuan</b>        |

Now please consider all the attributes described above: **weather**, **temperature**, **congestion**, **air quality**, **presence of bike lanes**, **time** and **cost**. Which would you choose for each trip?

|        | Shared Bicycle | Shared Electric Bike | Same as Part II |
|--------|----------------|----------------------|-----------------|
| Trip 1 |                |                      |                 |
| Trip 2 |                |                      |                 |
| Trip 3 |                |                      |                 |

Demographics section omitted.

## Appendix A.4 – Third Survey Design

| Part-1                                                                                               |                                                                                                                                             |                                                                                                                                                  | Part-2                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                      |                                                   | Part-3                                                                                                                                                               |                                |                          |                                 | Part-4                                                                                                                                                                                                                                            |
|------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------|---------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------|--------------------------|---------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Think back to yesterday. Tell me about all the trip links you made in the following distance ranges: |                                                                                                                                             |                                                                                                                                                  | Now suppose that it is <b>sunny</b> , 20 °C, the air quality is <b>bad</b> and congestion is <b>bad</b> . Also suppose, even though this may or may not be the reality for the trip you indicated, that bike lanes are available for <b>all of the trip</b> .<br><br>Given these conditions, please indicate the transportation mode you would typically choose for each of the above trips, and please indicate the approximate cost and travel time for each selected mode. |                                                                                                      |                                                   | Suppose for each of the above trips that you had the opportunity to instead use a shared bicycle or shared electric bike. The costs and travel times are as follows: |                                |                          |                                 | Now please consider the costs and travel times as well as all the attributes described in Part-2: it is <b>sunny</b> , 20 °C, the air quality is <b>bad</b> , congestion is <b>bad</b> and bicycle lanes are available for <b>all</b> of the trip |
|                                                                                                      | <b>Origin</b><br>1= home<br>2=work<br>3=school<br>4=store<br>5=restaurant<br>6=entertainment<br>7=transit facility<br>8=bus stop<br>9=other | <b>Destination</b><br>1= home<br>2=work<br>3=school<br>4=store<br>5=restaurant<br>6=entertainment<br>7=transit facility<br>8=bus stop<br>9=other | <b>What Mode Would you Choose?</b><br>1=bus<br>2=car (drive alone)<br>3=car (passenger)<br>4=ebike<br>5=bike<br>6=walk<br>7=taxi<br>8=motorbike<br>9=other                                                                                                                                                                                                                                                                                                                    | <b>What would the approximate trip cost be? (include fare, tolls, parking, and approximate fuel)</b> | <b>What would the approximate travel time be?</b> | <b>Public bike cost</b>                                                                                                                                              | <b>Public bike travel time</b> | <b>Public ebike cost</b> | <b>Public ebike travel time</b> | <b>Which would you choose for each trip?</b><br>1=same as Part-2<br>2=public bike<br>3=public <u>ebike</u>                                                                                                                                        |
| 0-1 km                                                                                               |                                                                                                                                             |                                                                                                                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                      |                                                   | 1 元                                                                                                                                                                  | 5 分钟                           | 2 元                      | 3 分钟                            |                                                                                                                                                                                                                                                   |
| 1-2 km                                                                                               |                                                                                                                                             |                                                                                                                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                      |                                                   | 1 元                                                                                                                                                                  | 12 分钟                          | 2 元                      | 11 分钟                           |                                                                                                                                                                                                                                                   |
| 2-3 km                                                                                               |                                                                                                                                             |                                                                                                                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                      |                                                   | 1 元                                                                                                                                                                  | 20 分钟                          | 2 元                      | 18 分钟                           |                                                                                                                                                                                                                                                   |
| 3-4 km                                                                                               |                                                                                                                                             |                                                                                                                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                      |                                                   | 1 元                                                                                                                                                                  | 27 分钟                          | 2 元                      | 24 分钟                           |                                                                                                                                                                                                                                                   |
| 4-5 km                                                                                               |                                                                                                                                             |                                                                                                                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                      |                                                   | 1 元                                                                                                                                                                  | 36 分钟                          | 2 元                      | 32 分钟                           |                                                                                                                                                                                                                                                   |
| 5-6 km                                                                                               |                                                                                                                                             |                                                                                                                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                      |                                                   | 1 元                                                                                                                                                                  | 44 分钟                          | 2 元                      | 38 分钟                           |                                                                                                                                                                                                                                                   |
| 6-7 km                                                                                               |                                                                                                                                             |                                                                                                                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                      |                                                   | 1 元                                                                                                                                                                  | 51 分钟                          | 2 元                      | 45 分钟                           |                                                                                                                                                                                                                                                   |
| 7-8 km                                                                                               |                                                                                                                                             |                                                                                                                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                      |                                                   | 1 元                                                                                                                                                                  | 59 分钟                          | 2 元                      | 53 分钟                           |                                                                                                                                                                                                                                                   |
| 8-9 km                                                                                               |                                                                                                                                             |                                                                                                                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                      |                                                   | 2 元                                                                                                                                                                  | 68 分钟                          | 3 元                      | 59 分钟                           |                                                                                                                                                                                                                                                   |
| 9-10 km                                                                                              |                                                                                                                                             |                                                                                                                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                      |                                                   | 2 元                                                                                                                                                                  | 75 分钟                          | 3 元                      | 66 分钟                           |                                                                                                                                                                                                                                                   |

Demographics section omitted.

## Appendix B - Travel Time Lookup Table

| Travel Time Lookup Table |                                     |        |
|--------------------------|-------------------------------------|--------|
|                          | Estimated Travel Times<br>[minutes] |        |
| Distance Range           | Bike                                | E-Bike |
| 1 km                     | 7                                   | 5      |
| 2 km                     | 13                                  | 10     |
| 3 km                     | 20                                  | 15     |
| 4 km                     | 26                                  | 20     |
| 5 km                     | 33                                  | 25     |
| 6 km                     | 40                                  | 30     |
| 7 km                     | 46                                  | 35     |
| 8 km                     | 53                                  | 40     |
| 9 km                     | 59                                  | 45     |
| 10 km                    | 66                                  | 50     |
| 11 km                    | 73                                  | 55     |
| 12 km                    | 79                                  | 60     |
| 13 km                    | 86                                  | 64     |
| 14 km                    | 92                                  | 69     |
| 15 km                    | 99                                  | 74     |
| 16 km                    | 106                                 | 79     |
| 17 km                    | 112                                 | 84     |
| 18 km                    | 119                                 | 89     |
| 19 km                    | 125                                 | 94     |
| 20 km                    | 132                                 | 99     |

## Appendix C – Training Material

### **Logistics**

#### Survey Forms

- Pick up forms at the office
- Conduct surveys in the order of the numbering in the Survey ID field
- Finish one whole block before starting the next!
- Return forms at the end of your shift
  - Drop off in the Transportation Research Lab – Room 110
  - If the lab is closed, drop off in the Transportation Research Lab's mailbox, located to the right of the front door of the hydrology building.
    - Do not leave GPS units in the mailbox!

#### GPS Logger

- Turn on when departing Tsinghua
- Leave on until you return to Tsinghua
- Every time someone completes a survey, press the Point of Interest button
  - Try not to push the POI button at any other times!
- Recharge the GPS logger after every use
- At the end of every shift, return the GPS unit to the Transportation Research Lab – Room 110.

## **In the Field – General Procedures**

Information you must share with every respondent

- Definitions
  - Trip link is one segment of continuous use of one mode of transportation. Every trip consists of one or more links. For example, if I ride my bike to the subway, take the train, and then walk 1 km, that would be a single trip with three links.
  - Bikeshare is bikes that are available for short term use by the public, where you can pick up a bike from a station near your origin and drop the bike off at a station near your destination, where it could be used by another user.
  - Congestion refers to both the road network and crowdedness of the subway trains and buses.

Other Definitions you may be asked about

- Bike lanes are any facilities designated for cyclists, protected or otherwise.
- Travel Costs
  - For personal automobile they include gasoline and parking
  - For transit they include the cost of fare
- Travel Time
  - For cars and taxis it is the time you spend in the car, so it includes time spent parking.
  - For transit, it includes the time spent waiting!

## **In the Field – Sampling Each Mode**

You will only sample one mode at a time. We will tell you ahead of time which modes to sample for each period. If you are not getting results at our suggested location, you can move, but do not change the mode you are sampling.

### *Pedestrians*

- Pick a line in the sidewalk
- Ask the *first* person who crosses that line to fill out the survey
- Ignore other pedestrian while the respondent is filling out the survey

### *Bicycles and E-bikes*

- Go to bicycle rack or e-bike parking area
- Ask the *first* person who parks a bike to fill out the survey
- Ignore other cyclists while the respondent is filling out the survey

### *Subway*

- Stand near the entrance of a subway
- Pick a line in the sidewalk close enough to the entrance that only subway users are crossing it
- Ask the *first* person who crosses that line to fill out the survey
- Ignore other pedestrian while the respondent is filling out the survey

### *Bus*

- Go to a bus stop
- Follow same procedure as subway

### *Personal Automobile*

- Go to a large parking lot
- Find an area where people are walking to and from their cars
- Use the same method as for pedestrians
  - But, you must ask them if they drove here.

### *Taxi*

- Go to an area where there is a lot of taxi activity
- Ask the first person you see trying to wave down a taxi or exiting a taxi to fill out the survey

## In the Field – Script

- Approach candidate and ask if they will participate
- Introduce project
  - Disclaimer
    - *Would you like to participate in our voluntary survey. Although there is no consequence for not participating, we will be happy to offer you this [souvenir, wet wipes, train ticket etc...] for taking the time to fill out.*
  - Beijing's new public bicycle system
    - *Have you heard about Beijing's new public bicycle system?*
    - *A public bicycle system is network of shared bikes. You can pick one up at a station near your origin and drop it off at station near your destination. Once you drop it off it is available for someone else to rent.*
    - *Would you like to take a few minutes to participate in a survey that will help us understand how this system will work in Beijing?*
  - Person Agrees
    - *Great, let's go through the survey one section at a time. At the start of each new section I will briefly explain what needs to be done.*
- Orientation
  - Section-1
    - *A trip link is a segment of a trip where you continuously travel using the same mode. Each trip consists of one or more links. For example, if you walk to the train station, take the train to downtown, and then walk to work, that is one trip with three links. Please describe yesterday's trip links.*
  - Section-2
    - *Now we want you to think about the trips you described in Part 1, but imagine that certain attributes have changed. Specifically, we are interested in how weather, temperature, air quality and congestion affect your travel decision making process.*
    - *Congestion refers to both the road network and crowdedness of the subway trains and buses.*
  - Section-3
    - *Now, please imagine that you had chosen a bicycle or e-bike for each of the trips described in Part 1. Can you please tell us how long it would take to make those trips with these modes? If you want, we can make suggestions based on average travel speeds in Beijing.*
  - Section-4
    - *Now, considering the environmental attributes described in Part-2 and the costs in Part-3, would you choose one of the public bike options, or would your original choice stand?*
  - Section-5
    - *Please share some information about yourself with us. Remember this survey is completely anonymous.*

## **Frequently Asked Questions and Comments**

Q1. I don't know exactly how much I spend on gas to make that trip.

→ *That's not a problem. You can just make a rough guess.*

Q2. But I wouldn't even consider using a bike. I get too sweaty.

→ *Great, please indicate the mode you would use in Part 2. In Part 4 indicate that you would not use the public bikes.*

Q3. For trip links should I even include things like walking from the bicycle rack to the building?

→ *No, we are only interested in trip links about one half kilometer or longer.*

## Vita

Andrew A. Campbell has worked and experienced the transportation systems in three different states and two countries. He spent five years working in the bicycle transportation industry managing facilities that provide secure bicycle parking at light rail stations. During that time he also done consulting for bicycle technology and bikesharing companies. In the Spring Semester 2011 he received a Bachelor of Science from the University of California, Berkeley, in the field of Civil and Environmental Engineering. At that time he met his adviser, Dr. Megan Ryerson, as she was finishing her postdoctoral research. The following semester he enrolled as her student at The University of Tennessee, Knoxville. He spent two semesters working as a graduate teaching assistant while pursuing a Master of Science in the department of Civil and Environmental Engineering. In the spring of 2012 he was awarded the National Science Foundation's East Asia and Pacific Summer Institutes for U.S. Graduate Students fellowship. He was also awarded W.K. McClure Scholarship for the Study of World Affairs. These generous awards funded him to spend the summer living in Beijing conducting research on shared public bicycle systems. Andrew graduated with Master of Science in December, 2012.