# ADDRESSING DECLINING BICYCLE USE IN CHINA: FACTORS ASSOCIATED WITH BICYCLE OWNERSHIP AND USE

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# Addressing Declining Bicycle Use in China: Factors Associated with Bicycle Ownership and Use

## Abstract

China is experiencing a drastic decline in bicycle use and substantial increase in auto travel. This major mode shift has significant social as well as environmental implications. In addressing the diminishing cyclist population, the Chinese government issued policy guidelines featuring benchmarks to sustain bicycle use. However, such guidelines were based on limited understanding of who choose to bike and why. The purpose of this study is to provide a better understanding of factors associated with bicycle ownership and use as a basis for developing measures and incentives to promote the use of bicycles in China. A nation-wide online survey was conducted to understand the characteristics of bicycle users and public attitudes towards bicycling. Logistic regression models were then used to test the importance of bicycle infrastructure and other physical environment factors relative to socio-demographic factors and personal attitudes. The results showed strong correlations of higher bicycle ownership and use with lower household income, shorter commute distance, leveraged bicycle infrastructure, positive attitudes towards cycling and negative attitudes towards automobiles. Similar regression analysis was also used to explore the influence of various factors on propensities for future bicycle use. Further, the study revealed substantial geographic variance of bicycle use within the country.

**Key words**: Bicycling, China, Travel Behavior, Public Attitudes, Logistic Regression

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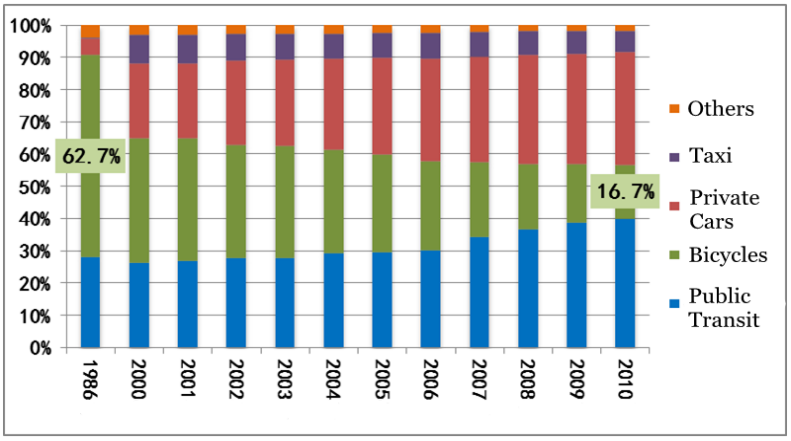
# 1. INTRODUCTION

Chinese cities are confronted with tremendous challenges to maintain economic growth and at the same time improve environmental quality and provide affordable and equitable services to urban residents. For many years, urban transportation strategies in Chinese cities have been based on temporary congestion relief and travel time savings. Priorities were given to increasing highway capacities and expansion of expressways. The result of such unbalanced development is that the ownership and use of automobiles skyrocketed while the walking and bicycling environment rapidly deteriorated.

From the 1990s to 2010 the national cyclist population declined at an annual rate of 2%-5%[1]. In contrast, the number of registered vehicles increased more than 12 fold, from merely 5.54 million in 1990 to 70 million in 2010[2]. As cars were gaining increasing popularity bicycles were marginalized. For instance, Beijing used to have one of the highest bicycle ridership rates in China, yet since the mid-1990s the mode share of bicycles in Beijing dropped from 62.7% in 1986 to 38.5% in 2000 and decreased even lower to 16.4% in 2010[3] (Figure 1.1). Shenzhen, another metropolitan center in the south east of the country, has experienced even more drastic decline of bicycle use from 40% in 1995 to nearly 4% in 2007[4].

**Figure 1.1 Mode Shares in Beijing form 1990 to 2010 (walking not included)[5]**

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The rapid motorization does not change is fact that the majority of Chinese households do not own cars and rely primarily on public transport, bicycles and walking. In fact, until 2011, nearly 20% of the national population commuted by bicycles and only 14% of the population commuted by private cars[6]. While China has become the largest automobile manufacturing and consuming country in 2009[7], the per capita of vehicles on road is still substantially lower compared to developed countries. Measuring with "automobiles ownership per 1000 capita", China only ranked 115th in the world in 2013[8].

In more recent years, Chinese cities faced with worsening traffic congestion and air pollution began to realize it was impossible to "build their way out of congestion". Policies were pushed forward to discourage automobile use and to seek alternative ways to meet increasing travel demand. Specifically, the national strategy of Public Transit Priority adopted in 2005 stipulated major investments in public transportation[9]. To encourage transit use, cities such as Beijing, Chengdu and Changsha initiated considerable a transit fare cut. Transit ridership began to increase gradually in spite of the growth of automobile use in most cities. However, as an unintended result, fare reduction had an negative effect on bicycle use. Coupled with the already deteriorated bicycling environment, lower transit fare makes bicycling a even less viable mode choice for Chinese urban dwellers who have to commute increasing distances.

Such drastic decline of once pervasive bicycle has significant social as well as environmental implications. On one hand, as Chinese cities accommodate themselves to motor vehicles by widening urban roads and expanding expressways, the interests of the majority who rely on non-motorized modes are sacrificed. On the other hand, decline in bicycle use and increase in automobile use contribute significantly to rising carbon emissions and worsening air quality. To date, air pollution has been perceived as the biggest health threat nationally. In Beijing for example, the PM2.5 measurement went "beyond index" for four times during 2010 and 2011.

In 2012, the Chinese national government issued the first set of policy guidelines addressing bicycling decline. The document stipulated that by 2015 urban areas with population over 10 million are to reach a share of bicycling and walking at 45%, and called attention for establishing bicycle lane networks, providing sufficient bicycle parking facilities and the integration of bicycle networks and public transit systems[10].

However, in the absence of political incentives and fiscal support, the benchmarks set

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China. National Development and Reform Comission. Planning Division. *Energy Conservation and Emission Reduction Plan for the 12th-Year Plan*. Beijing: NDRC Publication, 2012. Print.

in the guidelines are out of reach for many major cities, given the fast expansion of urban areas, rapid increase in transportation demands as well as the economic growth brought by the automobile industry. For instance, Beijing aimed to only retain a bicycle share of 18% in 2020, a continuation of the 4% annual decline of mode share since in 2000[11]. Similarly, many cities have issued local government policies in response to the national guidelines, yet these documents lacked detailed implementation plans to encourage bicycle use despite vague benchmarks.

Given the strong existing bicycle industry, the remaining high level of bicycle ownership among urban residents, and the shrinking but still preserved bicycle lane networks, Chinese cities still have a chance to revive bicycle use as an integral part of their sustainable future. To achieve this goal, much more progressive bicycle planning and policies should be carried out.

The purpose of this study is to provide a better understanding of the factors associated with bicycle ownership and use as a basis for developing measures and incentives to promote the use of bicycles in China. A nation-wide online survey was conducted to understand the characteristics of bicycle users and public attitudes towards bicycling. Logistic regression models were then used to test the influence of socio-demographic factors, attitudes and physical environment factors on bicycle ownership, bicycle use and propensities for future bicycle use.

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# 2. LITERATURE REVIEW

Proactive government interventions have been proven to be critical to encourage bicycle use. This is affirmed by a comprehensive review of 162 existing papers on the effectiveness of various interventions on levels of bicycling[12]. The Chinese government has issued policy guidelines at both national and local levels to address the decline of bicycle use. Nevertheless, such guidelines are provided with little understanding of the bicycle users characteristics and the factors associated with their mode choices.

The existing literature provides ample explanation regarding bicycle travel behavior. Inducing factors that are most commonly cited include improved cycling facilities[13], improvement of cycling safety[14], increase in the dedicated bicycle lanes[15], and enhanced integration between bicycle and public transit infrastructure[16]. In contrast, the most often cited factors preventing people from cycling range from travel distance[17], gradient[18], traffic safety, heavy traffic, inconsiderate drivers, pollution to bad weather[19].

However, this evidence drawn from developed countries has limited implications for China, simply because none of these countries has ever witnessed a bike share as high as 70%, as China did in 1980s, followed by a drastic annual decline of bicycle use at nearly 4%[20] since 1990. With its fast urbanization and motorization, China is facing unprecedented challenges in keeping bicycles on roads.

Unfortunately, the related studies in Chines context are rare. Most existing research on bicycle mode choice in China ends to use a micro-scale approach, focusing on the qualitative analysis of the impact of technical parameters such as road configuration,

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[20] Du, Yu, comp. "Interview with Bingren Li, Head Economist of China Housing and Urban & Rural Development Bureau." China News. "Declining Bicycle and Pedestrian Transportation in China.", 02 Sept. 2009. Web. 11 Oct. 2013.

travel distance, travel time, and bicycle facilities on bicycling levels[21]. Other research has limited policy implications at the national due to geographic limitations[22] or the focus on narrower topics such as public bicycles and electric bicycles[23].

This paper aims to address this gap by understanding the factors contributing to bicycle ownership and use with a quantitative approach. Both a decision making model[24] and diffusion theory[25] were used to understand bicycle mode choice in existing literature. The methodologies in this study was heavily influenced by a study of factors associated with bicycle ownership and use in six small U.S cities[26].

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# 3. METHODOLOGY

The study provides a cross-sectional understanding of the relative influence of socio-demographic factors, personal attitudes and physical environment on current bicycle ownership, current bicycle use and the likelihood of future bicycle use. The unit of the research is individual. A nation-wide online survey targeting adults was conducted between January 2014 and February 2014. The questionnaire was administered through www.people.com.cn and www.sina.cn, the two major online news portals in China that provide surveying service. The survey link was advertised in the news page of the websites, and recruiting emails were sent to their subscribers. In total, 3,312 responses were collected. After cleaning 3,067 of them remained, representing 29 cities across the country.

## 3.1 Survey Design

Survey respondents were asked four types of questions. The first type were socio-demographic questions including age, income, vehicle ownership and the city respondents were from. The second type dealt with attitudes and concerns, including opinions on biking, driving and mode choices. The third type captured respondents' perceptions of the travel environment, including distance, bike lanes and bicycle parking. Finally, the forth type was about biking behavior. They asked about information on current bike use, use of public bicycles, biking purposes, biking frequency, change of frequency and willingness to bicycle more in the future.

While the first three types of questions are explanatory to determine biking behavior, information in the forth category served both as dependent and explanatory variables. In addition, some of the questions in the forth type also defined the population for each model. Specifically, the question on public bicycle use was included to define people who had access to bicycles[27] and the question on biking frequency change was designed to separate former bicycle users from current bicycle users.

In total, the survey contained 26 questions. For the purpose of simplification all questions in the survey were designed to be categorical. Please see Appendix B for the complete survey questionnaire.

## 3.2 Data Cleaning

The completion rate for responses was only about 30%, with most responses containing one to two answers missing. To fully utilize all the information collected and to provide a sufficient sample size for regression analysis, all analysis were conducted only removing the missing value in the respective questions. Therefore the

[27] It was assumed that a respondent had access to bicycles if his/her household own a bicycle or he/she lives in an area where there is a bike share program.

valid sample size varies among different statistical analysis. The survey also contained questions asking for repeated information. For example, respondents were asked about biking purposes and biking frequency in two separate questions, both of which contain an option of "I don't use bicycles". Entries with conflicting information were removed, such as responses with the answer "I don't use bicycles" in the first question but indicated a biking frequency more than one time per week. After cleaning 3,067 responses were retained, some of which contained missing values.

### 3.3 Data Modeling

The study aims to examining three sets of issues: bicycle ownership, bicycle use and respondents' willingness to bike more in the future.

Model 1, Model 2 and Model 3 were employed to determine whether and to what extend various factors impact bicycle ownership and use. The models are based on the assumption that people make three distinct decisions to maximize their utilities: 1) to own or not own a bike, 2) to use or not to use bicycles, and 3) to use bicycles frequently (more than 3 times a week) or moderately. All three decisions could be affected by factors including socio-demographic characteristics, attitudes and concerns and perceptions of the physical environment.

For model 1-3, the sample group is different for each model. Given that the economic and social barrier for owning a bike is relatively low in China, all respondents are considered to have the choice of owning a bike. Thus Model 1 used the entire sample for analysis. In comparison, only those who have access to bicycles have the choice to use bicycles or not. Therefore Model 2 applied only to those with access to bicycles. "Having access to bicycles" is defined as either owning a bicycle in the household or living in an area where there is a bike share program. Similarly, the choice whether to bike frequently or moderately is only available for people who used bicycles. Hence, Model 3 only used responses indicating bicycle use.

Model 4, Model 5 and Model 6 were utilized to explore what factors affect respondents' willingness to bike more in the future and if there is a difference between current bicycle users, former bicycle users and people who had never biked. These three models have the same dependent variable (the answer to the yes-or-no question "Are you willing to bike more in the future if the biking environment improves?"). In addition, they have similar explanatory variables consisting of socio-demographic factors, attitudes and concerns as well as perceptions of the physical environment. What separates Model 4,5, and 6 is they were applied to different sample groups. While Model 4 was applied to respondents who were current bicycle users, Model 5 focused only on former bicycle users (people who were not current bicycle users and had used bicycle less than previous years) and Model 6 only applied to those who had never biked at the time of the survey (people who were not current bicycle users and had remained at the same bicycling level than previous years).

Dependent variables and explanatory variables in all six models are synthesized in the following table (Table 3.1).

**Table 3.1 Descriptions of Variables**

| Variable Name | Used in Model No. | Range | Description |
|---|---|---|---|
| **Dependent Variables** | | | |
| Bike Ownership | 1 | [0,1] | 0=Does not own a bike; 1=Owns a a bike |
| Bike Use | 2 | [0,1] | 0=Does not use Bikes as a means of transportation; 1=Uses Bikes as a means of transportation |
| High Frequency* | 3 | [0,1] | 0=Uses bikes 3 times or less than 3 times a week; 1=Uses bikes more than 3 times a week |
| Bike Future | 4,5,6 | [0,1] | 0=Will not consider biking more even if the biking environment improves; 1= Will consider biking more if the biking environment improves; |
| **Explanatory Variables** | | | |
| *City* | | | |
| Beijing | 1,2,4,5,6 | [0,1] | 0=Does not live in Beijing; 1=Lives in Beijing |
| Chengdu | 1,2,4,5,6 | [0,1] | 0=Does not live in Chengdu; 1=Lives in Chengdu |
| Hangzhou | 1,2,4,5,6 | [0,1] | 0=Does not live in Hangzhou; 1=Lives in Hangzhou |
| Ningbo | 1,2,4,5,6 | [0,1] | 0=Does not live in Ningbo; 1=Lives in Ningbo |
| Nanjing | 1,2,4,5,6 | [0,1] | 0=Does not live in Nanjing; 1=Lives in Nanjing |
| Qingdao | 1,2,4,5,6 | [0,1] | 0=Does not live in Qingdao; 1=Lives in Qingdao |
| Shanghai | 1,2,4,5,6 | [0,1] | 0=Does not live in Shanghai; 1=Lives in Shanghai |
| Shenyang | 1,2,4,5,6 | [0,1] | 0=Does not live in Shenyang; 1=Lives in Shenyang |
| Other Cities | 1,2,4,5,6 | [0,1] | 0=Does not live in cities other than Beijing, Chengdu, Hangzhou, Ningbo, Nanjing, Qingdao, Shanghai and Shenyang; 1=Lives in cities other than Beijing, Chengdu, Hangzhou, Ningbo, Nanjing, Qingdao, Shanghai and Shenyang |
| *Socio-demographics* | | | |
| Gender | 1,2,3,4,5,6 | [0,1] | 0=Male; 1=Female |
| Age | 1,2,3,4,5,6 | [1,3] | 1=Between 19~30 years old, 2= Between 31~50 years old, 3=Over 51 years old |
| Income | 1,2,3,4,5,6 | [1,5] | 1=Less than 800 RMB/m; 2=801~1,500 RMB/m; 3=,1500~9,000 RMB/m; 4=9,000~35,000 RMB/m, 5=More than 35,000 RMB/m |
| Car Ownership | 1,2,3,4,5,6 | [0,1] | 0=Does not own a car; 1=Owns a car |
| *Attitudes for Biking* | | | |
| Biking is Good for Health | 1,2,3,4,5,6 | [1,5] | Agreement that "Biking is good for people's health" on 5-point scale** |
| Bicycles are Low Emitters | 1,2,3,4,5,6 | [1,5] | Agreement that "Biking is the among lowest greenhouse gas emitter among all modes of transport." on 5-point scale** |

| Variable Name | Used in Model No. | Range | Description |
|---|---|---|---|
| Bicycles are Part of Chinese Tradition | 1,2,3,4,5,6 | [1,5] | Agreement that " Bicycle is a part of Chinese traditional culture." on 5-point scale** |
| Bicycles are Part of Modern Society | 1,2,3,4,5,6 | [1,5] | Agreement that "Bicycle is a symbol of modern society." on 5-point scale** |
| *Attitudes for Cars* | | | |
| Cars Impact on Air Quality | 1,2,3,4,5,6 | [1,4] | 0=very little; 1=some but limited; 2=modest; 3=considerable; 4=significant |
| Cars to be Reduced | 1,2,3,4,5,6 | [1,5] | Agreement that "In general there are too many cars on the road and the government should do something to reduce driving." on 5-point scale** |
| *Travel Concerns* | | | |
| Speed is Important for Traveling | 1,2,3,4,5,6 | [1,5] | Agreement that "Speed is a very important aspect when choosing the mode of travel." on 5-point scale** |
| Safety is Important for Travelling | 1,2,3,4,5,6 | [1,5] | Agreement that "Safety is a very important aspect when choosing the mode of travel." on 5-point scale** |
| *Biking Environment* | | | |
| Distance to Work | 1,2,3,4,5,6 | [1,4] | 1=Less than 3 km; 2=Between 3~7 km; 3= Between 7~10 km; 4=More than 10 km |
| Distance to Market | 1,2,3,4,5,6 | [1,4] | 1=Less than 3 km; 2=Between 3~7 km; 3= Between 7~10 km; 4=More than 10 km |
| Sufficient Bike Lane | 1,2,3,4,5,6 | [1,5] | Agreement that " In my city there are sufficient bike lanes on the road." on 5-point scale** |
| Bike Lane Available | 1,2,3,4,5,6 | [1,5] | Agreement that "Most bike lanes in my city are not occupied by cars parking and are available for use." on 5-point scale** |
| Sufficient Parking | 1,2,3,4,5,6 | [1,5] | Agreement that "There are sufficient bike parking spaces in my city." on 5-point scale** |
| Reasonable Parking Price | 1,2,3,4,5,6 | [1,5] | Agreement that "Charges of bike parking in my city are reasonable." on 5-point scale** |
| *Biking Purposes* | | | |
| Commute | 3,4 | [0,1] | 0=Does not use bikes for commute ; 1=Uses bikes for commute |
| Shopping | 3,4 | [0,1] | 0=Does not use bikes for shopping ; 1=Uses bikes for shopping |
| Exercise | 3,4 | [0,1] | 0=Does not use bikes for exercise ; 1=Uses bikes for exercise |
| Leisure | 3,4 | [0,1] | 0=Does not use bikes for leisure ; 1=Uses bikes for leisure |
| Others Purposes | 3,4 | [0,1] | 0=Does not use bikes for purposes other than commute, shopping, exercise or leisure ; 1=Uses |

| Variable Name | Used in Model No. | Range | Description |
|---|---|---|---|
| | | | bikes for commute for purposes other than commute, shopping, exercise or leisure |
| *Additional Questions* | | | |
| Current Frequency | 4,5 | [1,4] | 1=Bikes 1~2 days per week , 2= Bikes 3~4 days per week; 3=Bikes more than 5 days per week; 4 = Does not bike |
| Frequency Change | 4,5 | [1,3] | 1= Have biked less than previous years; 2= Have biked the same than previous years; 3=Have biked more than previous years |
| Public Bike | 2 | [1,3] | 1= Use public bikes; 2= Does not use public bikes; 3= There is no bike share program where the respondent lives |

* High Frequency is calculated based on the Current Frequency. High Frequency = 1 when Current Frequency > = 3.

** 1= Strongly disagree, 2=Disagree, 3=Neutral, 4=Agree, 5= Strongly Agree.

Binary logistic regression was used in all six models to examine the influence of various categorical factors on a dichotomous outcome by estimating the odds ratio of the event occurrence, for example owning bicycles or using bicycles. The log odds of the dichotomous dependent variable is calculated as oppose the dependent variable itself. A linear relationship between the logit of the dependent variable and explanatory variables and no linear relationships between the explanatory variables were assumed.

The intent of this study is to determine the relative significance and the direction of influence of the explanatory variables in explaining bicycling behavior. Therefore in interpreting the results attention should be paid to two factors: the significance level and the sign of the correlation coefficient. Lower significance level indicates the smaller possibility that the observed correlation is just due to chance alone. A positive coefficient indicates a positive relationship between the logit of the dependent variable and the explanatory variable, while a negative coefficient suggests the opposite. Additionally, the correlation coefficient of a given independent variable should be interpreted as the effect of a unit of change in the explanatory variable on the predicted log of the odds ratio of the binary dependent variable, with the other variables in the model held constant.

For variables that employed dummy coding, the value and magnitude of coefficients are relative to the reference variable to the same group. For instance in estimating the impact of cities on bicycle use, the direction and magnitude of coefficient estimates for other cities are relative to Wuhan as the reference. Cautions should be given when comparing the absolute values between the coefficients of two or more explanatory variables that utilize different coding schemes, for example age and “the important of speed when travelling”.

Given that the large number of explanatory variables compared to the sample size, a backward stepwise process was considered. However due to the prevalence of missing value which prevents the automatic process, the choice of predictive explanatory variables was carried out manually based on the criteria of P-value by removing statistically insignificant variables one at a time. For validation purposes, multi-collinearity was evaluated using variance inflation factors for all models and the results were found to be satisfactory.

## 3.4 Limitations

The limitations of the study come from multiple aspects. First the strategies available for sampling are limited for a nation-wide online survey. In fact empirical results showed a concentration of responses in large areas with strong urban economy and people from smaller and less affluent cities were under represented. Moreover, the survey only reached the population with access of Internet, which may result in the younger population and the population with higher income being over represented.

The fact that the survey is more likely to be appealing to those who feel strongly about biking issues also leads to problems associated with self-selection. In this case such misrepresentation of the general population was almost impossible to account for as there was no way to find out sample members who saw the survey link and decided not to participate. Additionally, due to the lack of interpersonal communication, questions on the online survey have greater chance to be misunderstood.

Another limitation involves the ambiguity of some survey questions, some of which could have been improved if more thorough considerations were given prior to launching the survey. For example in asking about respondents the change of biking levels, the question was framed as “Have you biked less, more or the same compared to the previous years?”. In this case, interpretation of the term “previous years” is subject to personal understanding. Similarly, the definition of biking environment” in the question “Are you willing to bike more in the future if the biking environment improves” can be affected by respondents’ subjective definitions of the future. Some issues with ambiguous questions are more difficult to resolve. For instance, defining the concept of “access to public bicycles” was challenging both because there is no term conveying the same meaning of “access” in Chinese and because the terminology is ambiguous by its own nature. Another example of this type is determining whether people use bicycles. An effective and accurate way of to know if people use bicycle is to ask if they had used bicycles in the past week. However given that the survey was conducted in winter when biking level was expected to be significantly lower than other seasons, the question was designed as “What means of transportation do you usually use?”.

In the survey three questions contained information that defines bicycle users. The first is the multiple choice question asking means of transportation the respondent used, which was designed to identify people who used bicycles. However only 45%

of respondents selected more than one options makes it less trustworthy to determine if those respondents actually use bicycles or not. The second and the third question asked about biking frequency and biking purposes, Both of providing the options "I don't' use bicycles". Answers to the question on biking frequency was chosen to determine bicycle users and answers to the other two questions were used to test the internal data consistency.

Large amount of missing data impose a major limitation to the study. The variation of valid sample size among different analysis diminishes the extent to which each analysis could be generalized to the entire survey population. Given that most questions were categorical with limited number of possible values, the applicability of various statistic methods to impute missing values becomes limited.

Finally, several statistical treatments limited the reliability of the statistical outcome. Manually removing statistically insignificant variables based on P-value could be considered arbitrary, especially when the predictability of the model, or the AIC factor, was increased because of the deleted variable. In addition, as with the controversial stepwise selection process, removing statistically insignificant variables is prone to over-fit the model and could possibly impose bias to the estimates of the remaining variables.[28]

The results of the study should be interpreted with precaution due to these limitations.

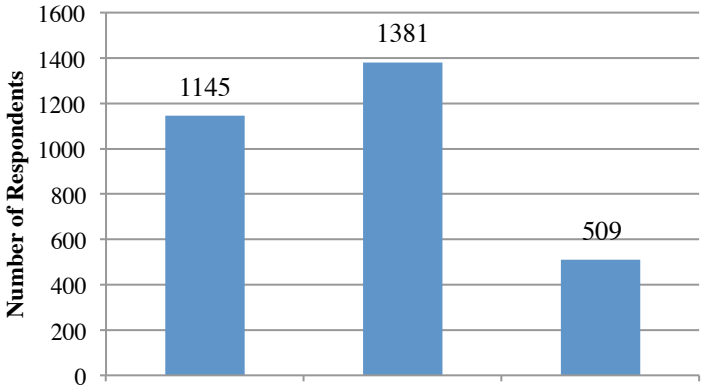
[28] Babyak, Michael A. "What you see may not be what you get: a brief, nontechnical introduction to overfitting in regression-type models." Psychosomatic medicine 66.3 (2004): 411-421.

# 4. FINDINGS

## 4.1 Socio-demographic Characteristics

3,067 valid[29] responses were collected in the survey. About 83% of the respondents were between the ages of 19 and 50 (Figure 4.1). There were approximately equal numbers of male (52.4%) and female (47.6%) respondents, indicating a fair representation of the overall urban population in China in terms of gender and age[30].

**Figure 4.1 Age Distribution of the Surveyed Population**
(Valid N= 3,035)




Population surveyed come from 27 cities across the country. Most (96%) responses concentrate in nine major cities (Table 4.1), namely Beijing, Chengdu, Hangzhou, Ningbo, Nanjing, Qingdao, Shanghai, Shenyang and Wuhan. These cities are the largest population clusters in China with urban populations around 10 million[31]. Among them, Beijing and Shanghai have the largest urban population of more than 20 million in 2013. These cities also have the strongest urban economies in the country. In 2013, the GDP per capita of the nine cities exceeded the national average by 20% to 120%[32]. The rest of the responses come from Emei, Baoding, Zhengzhou, Guangzhou, Jinan, Shijiazhuang, Xi'an, Heze, etc.

29 Missing data were included
30 The 6th China National Census Report, China Statistic Bureau, March 2011.
31 Population data come from 2013 Annual Economic and Social Development Report published by Municipal Statistics Bureau in each city in 2014.
32 GDP Per Capita data come from 2013 Annual Economic and Social Development Report published by Municipal Statistics Bureau in each city in 2014.

**Table 4.1. Population and GDP Per Capita of Surveyed Cities**

| City | % of Survey Population (n = 3,067) | Urban Population in 2013 (million) | GDP Per Capita in 2013 | |
|---|---|---|---|---|
| | | | Value (thousand dollars) | % of National GDP Per Capita in 2013 |
| Beijing | 13 | 21.2 | 15.4 | 223 |
| Chengdu | 11 | 14.0 | 10.5 | 152 |
| Hangzhou | 5 | 8.8[33] | 15.5 | 225 |
| Ningbo | 9 | 7.6 | 12.3 | 178 |
| Nanjing | 12 | 8.1 | 15.8 | 229 |
| Qingdao | 10 | 8.7 | 12.2 | 177 |
| Shanghai | 11 | 23.7 | 14.9 | 216 |
| Shenyang | 12 | 8.1 | 11.6 | 168 |
| Wuhan | 13 | 10.1 | 8.4 | 122 |
| Others | 4 | -- | -- | -- |

Partially due to such concentration of respondents in affluent cities, the income distribution of the respondents is tilted to higher economic classes (Table 4.2). Compared to an nation-wide online survey conducted by China Internet Association in 2007 which reported only 3% of the population surveyed with monthly household income greater than 9,000 RMB ( about 1,300 USD), the proportion of respondents in the same category in this study was as high as 50%. Such a difference is considered significant even if taking into account income inflation since 2007.

**4.2 Monthly Household Income Distribution: Survey vs. National Internet Users Survey[34]**

| Income Groups | Survey (%) | National Internet Users Survey (%) |
|---|---|---|
| Less than 800 RMB | 1 | 7 |
| 800-1,500 RMB | 12 | 20 |
| 1,500-9,000 RMB | 36 | 70 |
| 9,000-35,000 RMB | 36 | 2 |
| More than 35,000 RMB | 15 | 1 |
| Valid N | 2,934 | 50,786 |

The geographical and economic concentration of responses in the study have substantial impacts on the study outcomes. These large cities are experiencing dramatic increases in auto ownership and uses. Therefore the spatial and social competitions between bicycles and automobiles are expected to be especially fierce. At the same time, as a strong correlation between income and auto ownership proven

33 2012 Hangzhou Annual Economic and Social Development Report, Hangzhou Municipal Statistics Bureau February 2013.

34 " 2007 Annual Netguid China Internet Survey Report "China Internet Association & DCCI Internet Data Center, 2008.

to exist in emerging markets[35], the auto ownership is expected to be higher in the surveyed population than in the overall urban population in China. Such characteristics of the surveyed population reduces the generalizability of the study at the national level, especially to cities with smaller urban population and weaker economies.

## 4.2 Vehicle Ownership and Mode Choices

Despite the factors that potentially lead to reduced ownership for bicycles and increased ownership for automobile, bicycles are still the most commonly owned and used type of vehicle among the surveyed population (Table 4.3). In comparison, while 44% of respondents reported owning cars, only 33% of them listed private cars as one of their major means of transport. Such difference between auto ownership and auto use implies that proactive urban policies and planning should be adopted to encourage more biking and less driving before automobiles become the dominant transport mode, especially given the rapid growth in automobiles and the drastic decline of bicycle use. It is also worth noting that as much as 70% of respondents reported using public transit regularly, indicating robust transit networks in the surveyed cities and the potential for integration between transit systems and bicycle networks to encourage more bicycle uses. Respondents were asked to choose all vehicle types that they own as well as all modes they usually use, therefore the percentages for both ownership and use do not add up to 100%.

**Table 4.3 Share of Vehicle Ownership and Use**

| Vehicle | Ownership (%) | Use (%) |
|---|---|---|
| Bicycle | 50 | 48 |
| Private cars | 44 | 33 |
| Electric Bicycles | 28 | 21 |
| Motorcycle | 10 | 2 |
| Public Transit | -- | 70 |
| Walking | -- | 23 |
| Taxi | -- | 8 |
| Others | 2 | 2 |

n=3,067

## 4.3 Attitudes towards Bicycling and Perceptions of Biking Environments

The study reported more than half (52%) of the respondents not using bicycles. In fact, as much as 34% of the none-bike users used to bike in previous years prior to the survey, suggesting the loss of the legacy of intensive bicycle use in the country. Even

[35] Chamon, Marcos, Paolo Mauro, and Yohei Okawa. "Mass car ownership in the emerging market giants." Economic Policy 23.54 (2008): 243-296.

for the 48% of the respondents who reported being bicycle users, about 50% of them use bicycles only one to two times a week. In fact, in 2011 the mode share of bicycles, measured by the number of trips made yearly, ranges from 16%[36] in Beijing to 10% in Shanghai[37]. To encourage more bicycle use, the study provides insight to understand the public attitudes toward bicycles and perceptions of the bicycling environment.

The benefits for using bicycles are well understood by the respondents, as they overwhelmingly viewed using bicycles was beneficial for their health as well as the environment (Table 4.5). The results were also obvious when it comes to the social aspect of bicycles, given that 74% of the respondents agreed bicycles are part of Chinese traditional and 64% of the respondents viewed bicycles as a symbol of modern society.

**Table 4. 5 Attitudes to Bicycles and Perception of Environment**

| Statements | Agree* (%) | Neutral (%) | Disagree** (%) |
|---|---|---|---|
| *Attitudes toward Bicycles* | | | |
| Biking is good for people's health. | 86 | 8 | 5 |
| The bicycle is the lowest emitter of greenhouse gas among among all modes of transport. | 88 | 9 | 4 |
| Bicycles are part of Chinese traditional culture. | 74 | 16 | 10 |
| Bicycles are a symbol of modern society. | 64 | 21 | 16 |
| *Perceptions of Bicycling Environment* | | | |
| In your city there are sufficient bike lanes on the road. | 48 | 26 | 26 |
| Most bike lanes in your city are not occupied by cars parking and are available for use. | 37 | 24 | 40 |
| There are sufficient bike parking spaces in your city. | 40 | 24 | 36 |
| Charges of bike parking in your city are reasonable. | 42 | 31 | 27 |

n=3,067

* Responses with answers of "strongly agree" and "agree",

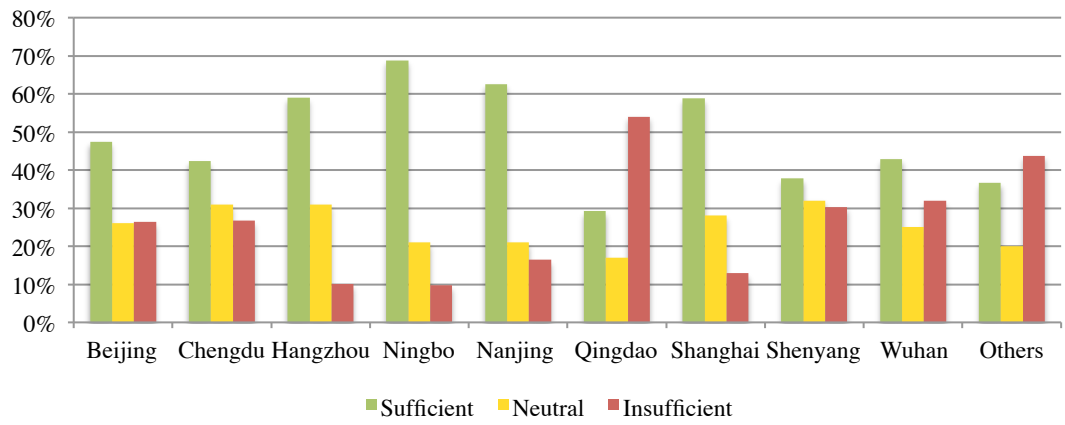
** Responses with answers of "strongly disagree" and "disagree"

Perceptions of the biking environment are mixed and vary greatly among cities. Nearly half of all respondents agreed there were sufficient bike lanes in their cities. Among the surveyed cities, respondents from Beijing, Hangzhou, Ningbo, Nanjing and Shanghai were overwhelmingly satisfied with adequacy of the bike lanes in their cities (Figure 4.2). In comparison, in Chengdu, Shenyang and Wuhan only a slight majority of respondents thought that the bike lanes were sufficient, with a significant portion (26%) of respondents considering them insufficient. Due to the mountainous topography and windy climate, few streets in Qingdao are equipped with bike lanes and therefore more than 50% of the respondents from Qingdao viewed the bike lanes

[36] Beijing Transportation Development Annual Report 2011, Beijing Transportation Research Center
[37] Shanghai Commission of Transportation and Construction, Shanghai Year Book 2011

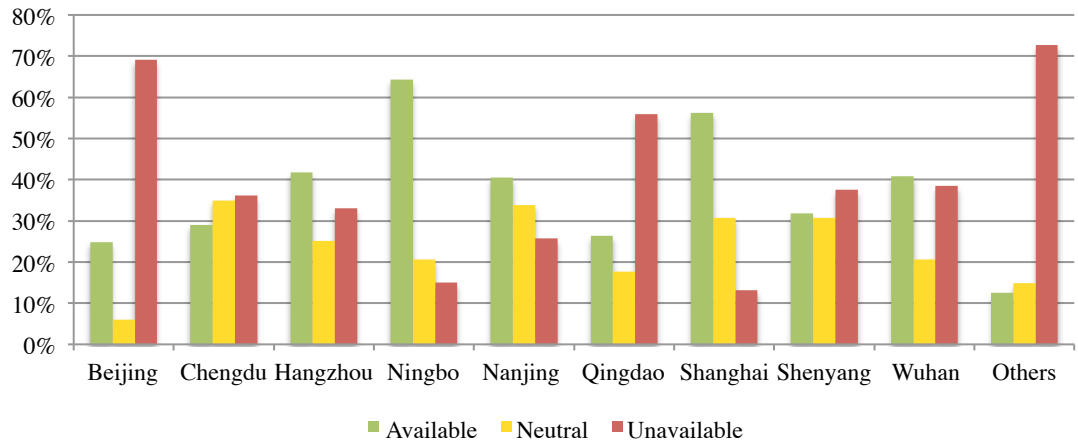
as inadequate. Respondents from the remaining cities also indicated dissatisfactions towards the adequacy of bike lanes.

**Figure 4.2 Perception of Bike Lanes Adequancy by City**




Most Chinese cities have bike lanes networks of some scale due to the history of intensive bicycle use. However as automobiles become more popular and increasing amount of road spaces are being allocated for cars rather than bicycles, having sufficient bike street in place does not grantee good experience using them. As much as 40% of all respondents held negative opinions about bike lanes availability. In fact, in some major Chinese cities, available parking spaces can no longer accommodate the fast increasing automobiles. As a result, bike lanes are occupied for on-street parking. The rights-of-way for bicycles have been sacrificed while cars getting in and out of parking spaces also poses considerable safety concerns for bicycle users. The survey showed that such phenomenon of cars encroaching bike lanes practically ubiquitous in Beijing as respondents overwhelmingly thought bike lanes were occupied by automobiles and not available for bicycle users despite their satisfactory with the amount of bike lanes (Figure 4.3). Respondents from Chengdu, Hangzhou, Nanjing and Shenyang expressed similar concerns. In comparison, respondents from Shanghai and Ningbo were satisfied with the availability of the bike lanes.

**Figure 4.3 Perception of Bike Lane Availability by City**




The availability and pricing of bicycle parking facilities impact people's choice to own or to to use bicycles. In generally respondents were not satisfied the status quo with bicycle parking. Especially in Beijing, Qingdao and Shenyang, respondents felt strongly about the bicycle parking issues (Figure 4.4, Figure 4.5). In contrast, respondents from Hangzhou, Ningbo, Shanghai and Wuhan held positive opinions for bicycle parking. Results from Nanjing and Chengdu were more ambiguous as the responses equal apart in positive and negative perceptions.

**Fiture 4.4 Perception of Bicycle Parking Adequancy by City**

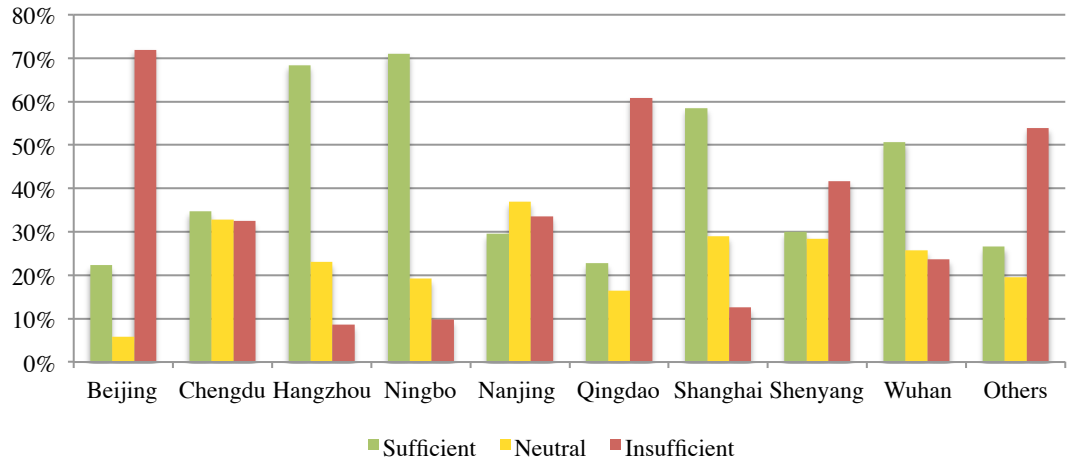
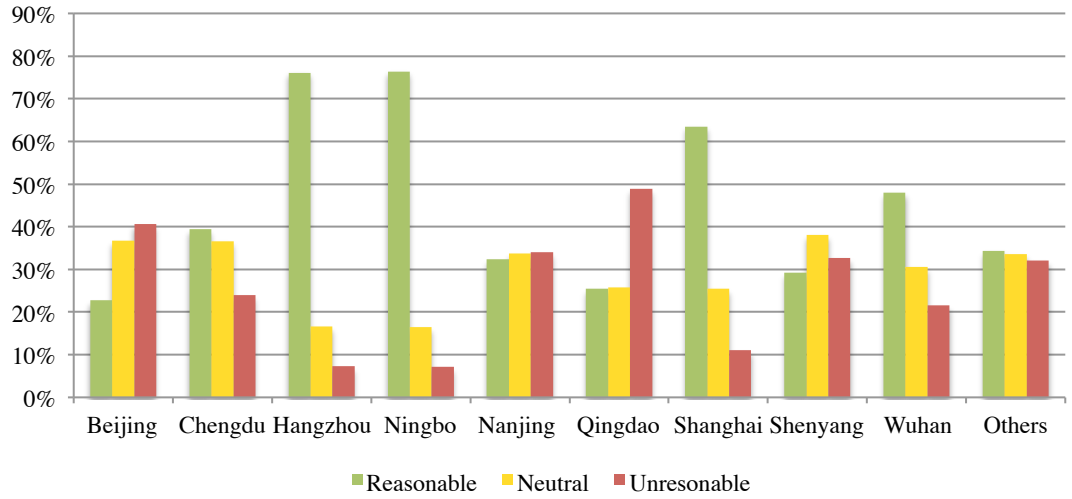


**Figure 4.5 Perception of Bicycle Parking Price by City**




The survey showed diverging results for public perception of the bicycling environment among cities. In Beijing, apart from increasingly longer commute distances as the city continues to expand, the lack of availability of bike lanes and the lack of adequacy and affordability of bicycle parking pricing make using bicycles especially difficult. However, given its shrinking but still preserved bike lane networks, Beijing still has a chance to restore its biking environment. In contrast, Shanghai, Hangzhou and Ningbo were perceived to have a satisfactory bicycling environment. The natural environment of Qingdao determines creating a bicycle-friendly city is challenging. The survey results in other cities, however, were too nebulous to draw detailed conclusions.

## 4.4 The Change of Biking Level

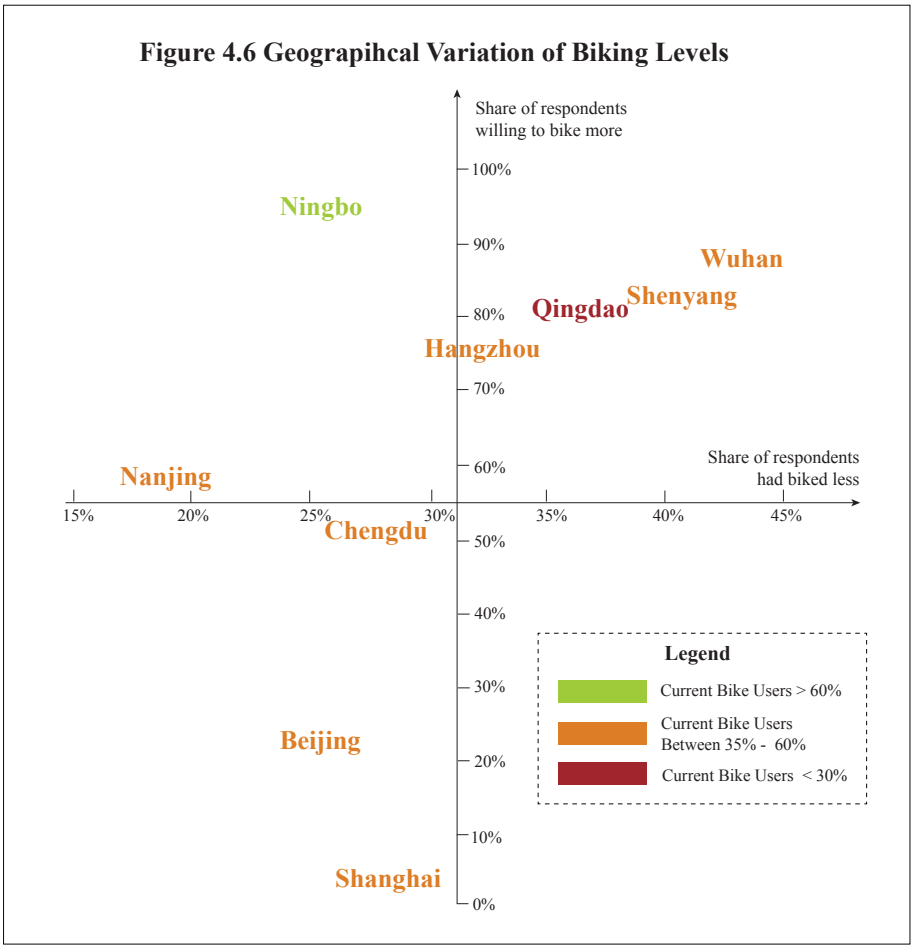
Over the past 20 years, China has experienced a steady decline in bicycle use[38]. This trend was clearly demonstrated in the survey as 31% of all respondents reported to had experienced a lower level of bicycle use at the time of the survey compared to the previous years. In fact, 34% of non-bicycle users suggested to be bicycle riders in the previous years prior to the survey.

Fortunately however, as much as 57% of all respondents indicated an interest to use bicycles more, pending on the improvement of the current bicycling environment. Both bicycle users (51%) as well as non-users (49%) expressed similar levels of interest to engage in more biking. In comparison, non-drivers indicated higher propensities (65%) for future bicycle use than drivers (45%). Chapter 4.6 provides further discussions on factors associated future bicycle use for current, former bikers and people who had never biked.

[38] Shaheen, Susan A., et al. "China's Hangzhou Public Bicycle." Transportation Research Record: Journal of the Transportation Research Board 2247.1 (2011): 33-41.

This section reveals the geographical variation of biking level across cities with three indicators, namely the decline of bicycle use, the current biking level and the willingness to bike more. Using the share of respondents that experienced a decrease in bicycle use and the share of respondents with an inclination to bike more, cities may be divided in three groups (Figure 4.6)[39].

**Figure 4.6 Geograpihcal Variation of Biking Levels**




The first group of cities are Ningbo, Nanjing and Chengdu. Respondents from these cities had experienced relatively less decline in bicycle use while showed high interests in biking more if the biking environment improves, therefore policies that encourage more bicycle use are expected to work well in these cities especially in Ningbo, as the large population of current bicycle users allows for more political incentives to improve the existing bicycle infrastructure.

The second group consists cities that had experienced higher decline in bicycle use but at the same time with higher percentage of respondents showing interests in biking more. Among these cities, Hangzhou, Shenyang and Wuhan had moderate to high share of bicycle users. With the sharp bicycle use decline, pro-bicycle policies are badly needed in these cities to address respondents' desires to bike more before it is too late.

[39] Other cities where the respondents do not concentrate are not included in the analysis.

Finally, Beijing and Shanghai showed moderate decline in bicycle use while low percentage of respondents with interest in bike more. It should be noted that Beijing had experienced a more drastic decline than the survey result indicate, as mode share of bicycles decreased from 32% to 16% in 2010[40]. A lower share of respondents willing to bike more in these two mega cities indicates these cities may have expanded too large for bicycle users. The auto-oriented urban planning and urban design have transformed the urban settings and land use patterns that were once conductive to bicycling and walking[41]. Encouraging more bicycle use in these two cities requires more effort as well as determinations on the part of policy makers and planners.

## 4.5 Factors associated with Bicycle Ownership and Use

Previous analysis revealed the interplay between multiple factors associated with bicycle ownership and use. Distinguishing the impact of personal factors (socio-demographics and attitudes) from factors associated with physical environment is important in that it contributes to understanding the effects of public policies targeting at different aspects in facilitating behavior changes. The study used logistic models to achieve such goal. The first three models aimed to gauge the impact of multiple factors on bicycle ownership and use (Table 4.6).

The results reinforced that apart from other factors, the level of bicycle ownership and bicycle use vary considerably among cities. Wuhan was used as a reference, positive coefficients indicated higher levels of bicycle ownership or use compared to Wuhan and negative confidents meant lower bicycle ownership or use. For frequency of bicycle use, no substantial geographical difference was captured from initial analysis and therefore cities were not included in the third model.

Apart from geographical differences, socio-demographics and physical environment factors played dominant roles in explaining household bicycle ownership. In general, younger people with lower income were more likely to own bicycles, which conforms with the experiences elsewhere in the world. Surprisingly, the results showed a positive correlation between car ownership and bicycle ownership. Given that only 40% of all respondents owned cars, such outcome could be an artificial effect raised by limited sample size rather an indication of a negative correlation between car ownership and income levels. Shorter commute distance from home to work and from home to market also contribute to higher bicycle ownership. Respondents living in cities with available bike lanes and affordable bicycle parking are more likely to own bicycles. In addition, respondents that viewed bicycling as good for the environment and agreed with the statement that the number of automobiles should be reduced are

[40] Beijing Transportation Research Center

[41] Cervero, R., & Day, J. (2008). Suburbanization and transit-oriented development in China. Transport Policy, 15(5), 315-323.

more inclined to own bicycles. Interestingly, bicycle owners were less concerned about travel speed than those who did not own bicycles.

**Table 4.3 Factors Associated with Bicycle Ownership and Use**

| Variable Name | Model 1: Own a bike vs. Not own a bike | | Model 2: Use bikes vs. Do not use bikes | | Model 3: Frequent Biker vs. Non-Frequent Biker | |
|---|---|---|---|---|---|---|
| Model Group | All | | People with Access to Bike | | Bike Users | |
| Valid N | 2799 | | 2464 | | 1356 | |
| | Coefficient | Signif. Level | Coefficient | Signif. Level | Coefficient | Signif. Level |
| ***City*** | | | | | | |
| Beijing | 0.40238 | * | 0.44828 | * | x | x |
| Chengdu | -0.38171 | . | -0.01792 | | x | x |
| Hangzhou | -0.5821 | * | -0.868 | *** | x | x |
| Ningbo | -0.54865 | ** | 0.83609 | *** | x | x |
| Nanjing | 0.48505 | ** | -0.16557 | | x | x |
| Qingdao | -1.35017 | *** | -0.65784 | ** | x | x |
| Shanghai | 0.38403 | *** | 0.64975 | *** | x | x |
| Shenyang | -0.38308 | * | -0.82616 | *** | x | x |
| Other Cities | 0.13674 | *** | -0.46532 | . | x | x |
| ***Socio-demographics*** | | | | | | |
| Gender | -- | -- | -0.33899 | *** | 0.19632 | . |
| Age | -0.18239 | ** | -- | -- | -0.20667 | * |
| Income | -0.27797 | *** | -0.37164 | *** | -0.42915 | *** |
| Car Ownership | 0.3469 | *** | -0.2803 | ** | -- | -- |
| ***Attitudes for Biking*** | | | | | | |
| Biking is Good for Health | -- | -- | 0.2164 | *** | -- | -- |
| Bike is Low Emitter | 0.24909 | *** | -- | -- | -- | -- |
| Bike is Part of Tradition | 0.11067 | . | -- | -- | -- | -- |
| Bike is Part of Modern Society | -- | -- | -- | -- | -- | -- |
| ***Attitudes for Cars*** | | | | | | |
| Cars Impact on Air Quality | -- | -- | 0.10702 | * | -- | -- |
| Cars to be Reduced | 0.22189 | *** | 0.35722 | *** | -- | -- |
| ***Travel Concerns*** | | | | | | |
| Speed is Important for Traveling | -0.29874 | *** | -0.27773 | *** | -0.35851 | *** |
| Safety is Important for | -- | -- | -- | -- | -- | -- |

| Variable Name | Model 1: Own a bike vs. Not own a bike | | Model 2: Use bikes vs. Do not use bikes | | Model 3: Frequent Biker vs. Non-Frequent Biker | |
|---|---|---|---|---|---|---|
| Travelling | | | | | | |
| ***Biking Environment*** | | | | | | |
| Distance to Work | -0.35127 | *** | -0.44202 | *** | -0.19212 | ** |
| Distance to Market | -0.30774 | *** | -- | -- | -0.2011 | * |
| Sufficient Bike Lane | -- | -- | -- | -- | -- | -- |
| Bike Lanes Available | 0.26944 | *** | -- | -- | -- | -- |
| Sufficient Parking | -- | -- | -- | -- | -- | -- |
| Reasonable Parking Price | 0.16302 | ** | 0.20717 | *** | -- | -- |
| ***Biking Purposes*** | | | | | | |
| Commute | x | x | x | x | 0.8789 | *** |
| Shopping | x | x | x | x | 0.24786 | * |
| Exercise | x | x | x | x | -- | -- |
| Leisure | x | x | x | x | -- | -- |
| Others Purposes | x | x | x | x | -- | -- |

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1'

--: Not Significant

x: Not in the model

50% of the all respondents claimed to be bicycle owners, whose decision of using bicycles were also affected by a number of factors. Generally, male bicycle owners used bicycles more than their female counterpart. Again, an inverse relationship between income and bicycle use can be observed. While car ownership was found to be positively correlated with bicycle ownership, it negatively contributed to bicycle use for bicycle owners. Nevertheless, bicycle owners who agreed that biking is good for their health were more likely to use their bicycles. Similarly, shorter commute distance, affordable bicycle parking prices, more concerns over automobiles and less concerns over travel speed also contributed to the propensity to use bicycles.

Of all bicycle users, 67% them reported to be frequent users. Fewer factors were found to have an impact on biking frequency. There was a strong correlation between lower income and higher frequency of bicycle use. Frequent bicycle users tended to have shorter commute distance and cared less about travel speed. Additionally, bicycle users were inclined to bike more often for commute and grocery shopping compared to exercise, leisure and other purposes.

Second, the fact that auto ownership correlated positively with bicycle ownership while negatively with bicycle use implies that as long as bicycle owners were given the option of personal mobility they are likely to forfeit the option of using bicycles. This finding corresponds with the increase of automobile travel and the decline of bicycle use over the last two decades. As bicycles being the choice of the poor and

bicycle users the victims of externalities imposed by drivers, biking is being perceived as a inferior travel option. Such public perception, once established, is very difficult to change despite the potential improvement of biking environment.

## 4.6 Factors associated with Future Bicycle Use

The second three models examined the relative influence of multiple factors on respondents' interests for biking more in the future. Cities were included as a explanatory variables to increase the accuracy of the coefficients for the remaining factors. To examine the possible differences between the three groups, Model 4 and Model 5 were applied to current and former bicycle users[42] and Model 6 was applied to respondents that had never used bicycles[43] by the time the survey.

43% of current bicycle users claimed to be interested in increasing their biking level. For them, none of the socio demographic factors remained to be significant in explaining inclinations for biking more. However, shorter commute distance, agreement with that biking is good for health and having bike lanes available for use increased the likelihood of willing to bike more. Moreover, current bicycle users who used a bicycle for their commute showed a higher willingness to bike more in the future(Table 4.7).

Among former bicycle users, 54% of them indicated an inclination to bike more. It should be noted that the sample size of this group was small so that the results from the regression analysis should be interpreted with caution. Lower income respondents were more likely to be interested in biking more. Similarly, shorter commute distance strongly correlated with higher likelihood to bike more. Former bicycle users who owned cars showed less inclination to bike more than those who did not. Demonstrations of environmental consciousness also contributed higher propensities to bike more in the future. Further, having sufficient bike lanes in the city was found to be conductive for getting former users back on bicycles.

For those who had never used bicycles, 57% of them indicated a willingness to bike more in the future. Socio-demographic factors played important roles in accounting for greater interests in biking more. Younger people with higher household income and shorter commute distance are more likely to be interested in biking more. Additionally, people agreeing with the notion that biking is good for health and cars have negative impacts on air quality were also more prone to be willing to bike more in the future.

[42] Former bicycle users were defined as none-current bicycle users who indicated a lower level of biking now compared to the previous years.
[43] People that never used bicycles were defined as none-current bicycle users that indicated the same level of biking in the past.

**Table 4.7 Factors Associated with Interests in Biking More**

| Variable Name | Model 4 | | Model 5 | | Model 6 | |
|---|---|---|---|---|---|---|
| **Model Group** | **Current Bikers** | | **Former Bikers** | | **People Never Biked** | |
| Valid N | 1374 | | 347 | | 801 | |
| | **Coefficient** | **Signif. Level** | **Coefficient** | **Signif. Level** | **Coefficient** | **Signif. Level** |
| ***City*** | | | | | | |
| Beijing | -1.29368 | *** | -1.6187 | *** | -1.7819 | *** |
| Chengdu | -1.46214 | *** | -1.66542 | * | -1.01898 | * |
| Hangzhou | 0.09582 | | -0.5271 | | -0.68338 | |
| Ningbo | 0.5944 | | -0.64722 | | 0.4643 | * |
| Nanjing | -0.30961 | | -0.05402 | | -1.1865 | *** |
| Qingdao | -0.72332 | | -0.96656 | | -0.17395 | |
| Shanghai | -1.80483 | *** | -1.91579 | *** | -1.32892 | *** |
| Shenyang | -0.06007 | | -0.53169 | | -1.05189 | * |
| Other Cities | -1.89063 | *** | -1.27845 | | -1.68141 | *** |
| ***Socio-demographics*** | | | | | | |
| Gender | -0.35909 | . | -- | -- | -0.35594 | . |
| Age | -- | -- | -- | -- | -0.64162 | *** |
| Income | -- | -- | -0.75483 | ** | -0.3564 | * |
| Car Ownership | -- | -- | -0.99482 | * | -- | -- |
| ***Attitudes for Biking*** | | | | | | |
| Biking is Good for Health | 0.44766 | *** | -- | -- | 0.55856 | *** |
| Bike is Low Emitter | -- | -- | 0.57106 | * | -- | -- |
| Bike is Part of Tradition | -- | -- | -- | -- | -- | -- |
| Bike is Part of Modern Society | -- | -- | -- | -- | -- | -- |
| ***Attitudes for Cars*** | | | | | | |
| Cars Impact on Air Quality | 0.22428 | * | 0.41627 | * | 0.14583 | . |
| Cars to be Reduced | 0.19015 | . | -- | -- | -- | -- |
| ***Travel Concerns*** | | | | | | |
| Speed is Important for Traveling | -- | -- | -0.4462 | . | -- | -- |
| Safety is Important for Travelling | -- | -- | -- | -- | -- | -- |
| ***Biking Environment*** | | | | | | |
| Distance to Work | -0.71908 | *** | -0.90652 | *** | -0.30211 | * |
| Distance to Market | -- | -- | -- | -- | -- | -- |
| Sufficient Bike Lane | -- | -- | 0.54019 | * | -- | -- |
| Bike Lanes Available | 0.27842 | ** | -- | -- | -- | -- |

| | | | | | | |
|---|---|---|---|---|---|---|
| Sufficient Parking | -- | -- | -- | -- | -- | -- |
| Reasonable Parking Price | -- | -- | -- | -- | -- | -- |
| ***Biking Purposes*** | | | | | | |
| Commute | 0.60089 | ** | x | x | x | x |
| Shopping | -- | -- | x | x | x | x |
| Exercise | -- | -- | x | x | x | x |
| Leisure | -- | -- | x | x | x | x |
| Others Purposes | -- | -- | x | x | x | x |
| ***Biking Frequency*** | | | | | | |
| Current Frequency | -- | -- | x | x | x | x |
| Frequency Change | -- | -- | x | x | x | x |

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1'

--: Not Significant

x: Not in the model

The results from Model 4, Model 5 and Model 6 shows that physical environment played an important role in encouraging more biking. Shorter commutes distance correlated with higher propensity to bike more for all groups of bicycle users. In addition, building adequate and available biking infrastructures are conductive to greater interests in future bike use, despite such correlation was less significant for those who had never used bikes. Awareness of environmental issues and biking as healthier way to travel were found to be strongly correlated with a interest in future bike use. Further, lower income people demonstrated a greater interest in future bike use. For former bike users, bicycling would serve as a viable transportation option as they also tended not to own automobiles.

# 5. CONCLUSION AND POLICY IMPLICATIONS

The study showed that bicycles, although with decreasing popularity, are still one of the most commonly owned and used means of transportation. Automobiles are entering Chinese households quickly despite local efforts in some major cities to curb their increase. At the same time, under the strong policy support, robust public transit systems are being built and improved in major cities across the country. In the new dynamic that Chinese cities are striving for, where public transit becomes as a major travel means, bicycles could serve as a complimentary mode that provides easy, clean and efficient last-mile service.

To sustain the current bicycling level and possibly restore the popularity of bicycle use, cities should take actions to curb urban sprawl and establish land use patterns and densities that are conductive to biking. Keeping housing and employment opportunities close enough is crucial for at least sustaining current bicycle use, as short commute distance was proven to be positively correlated not only with bicycle ownership and use, but also with inclinations to bike more in the future.

The shrinking but still preserved bicycle lane networks in Chinese cities serves as a notable advantage to restore bicycle use. Sufficient bike lanes and the enforcement of regulations to ensure the availability of these lanes are important to sustain bicycle ownership and people's interests in using bicycles in the future, although this study lacked direct evidences to support the notion that current bicycle use significantly correlates with bicycle lane networks.

Equally important are programs that aim to improve individual attitudes toward bicycling, as the analysis showed positive correlation between bicycling behavior and acknowledgement of the benefits of bicycling. Such findings indicate current efforts aiming at educating the public about the health and environmental benefits of bicycling should be continued and encouraged. The study also revealed negative attitudes towards automobiles are important in explaining current bicycle use and interest in future bicycle use, which indicates education on the externalities of driving could potentially be conductive to sustainable public behavior changes. Further, public education should target at promoting the images of on bicycles. As automobiles are rapidly entering Chinese households and viewed as symbols of status, sustaining the current positive perception of bicycles as part of Chinese traditional culture as well as modern society is critical to achieve the promise of sustainable cities.

International experience indicates proactive policy interventions are necessary for substantial increase in bicycling. Such interventions include expanding bicycle lane networks, increasing bicycle parking facilities and services, promoting pro-bicycle programs and education, carrying out bicycle-supportive land use planning and

restricting automobile use[44]. Specifically, the experience in Germany implies that with the right set of public policies, bicycles can be increased in spite of rapid suburbanization, increasing trip lengths and rising average income. The experience in Copenhagen further suggests that increasing bicycling levels require an integrated package of continuous, coordinated interventions with working evaluation and enforcement mechanisms[45].

The fact that current pro-bicycle policies in China at both national and local levels remain at ambiguous benchmarks raises concerns over whether bicycles will remain to be a viable mode choice for future urban residents with growing auto ownership and rising average household income. There is no doubt that the Chinese government should initiate more proactive interventions in addressing declining bicycle use, yet given the substantial geographic variation in bicycle use, to what extent national policies could influence bicycling behavior relative to local interventions remains an area for future research.

Despite the fact that lower income was found to be strongly associated with a greater likelihood of owing, using and frequently using bicycles as well a greater interest of future bicycle use, bicycles should not be positioned as an inferior mode of transport, but instead should be treated with respect in all aspects of policies and planning. After all, as income continues to grow in this country, restoring the legacy of intensive bicycle use means that bicycling will not only need to be the choice of the poor, but also the choice of the formerly poor as well as that of the younger generation who are never poor.

Chinese cities are standing in a critical historic crossroad. When changes are happening rapidly everywhere, every decision made today will impact the way of living for generations to come. With bicycle uses declining at an alerting pace, developing incentives to influence preferences and encourage sustainable behavior changes are of vital importance to ensure sustainable urbanization of the country. Planners and policy makers should realize the important role of bicycles in reduction of energy consumption and improvement of air quality. After all, improving bicycling environment does not only benefit bicycle users alone. Restoring human-scale street networks and improving urban facilities and street landscapes are important to build the livable communities and vibrant neighborhoods that Chinese cities desperately need.

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# Appendix B. Survey Questionnaire in English

1. Please choose your gender.

   □Male □Female

2. What is your age?

   □ 19 – 30 □ 31 – 50 □ 51 and more

3. What is your monthly household income level?

   □Less than 800 RMB/month □801-1500 RMB/month □4501-9000 RMB/month

   □9001-35,000 RMB/month □More than 35,000 RMB/month

4. Which city are you from?

   □Beijing □Shanghai □Guangzhou □Other: Please specify_____.

5. Do you or your household own a bicycle?

   □Yes □No

6. Do you use the bike share program?

   □Yes □No □There is no bike share program where you live

7. What are the means of transportation that you usually use? (Multiple Choices)

   □Car □Public Transport □Bicycle □Walk □Taxi □Others

8. How often do you usually bike?

   □1-2 days/week □3-4 days/week □more than 5 days/week □You usually don't use bikes

9. What are the primary purpose of your bicycle trips? (Multiple Choices)

   □Commute □Grocery Shopping □Exercise □For Fun □Others □You usually don't use bikes

10. Did you bike more during the past year than the previous years?

    □Yes □No

11. Are you interested in biking more if the biking environment improves?

    □Yes □No

12. How long is the distance from your home to your workplace/ school?

    □ Less than 3 km □3-7 km □7-10 km □more than 10 km

13. How long is the distance from your home to the nearest grocery store?

    □ Less than 3 km □3-7 km □7-10 km □more than 10 km

14. Does your household own a car?

□Yes □No

15. How much do you think is the air pollution problem caused by driving?

□ Very little □Some but limited □Modest □Considerable □Significant

Please indicate your agreement with the following statements by selecting one of the five options:

16. In my city many roads are bicycle-friendly and have bike lanes.

□ Strongly Agree □Agree □Neutral □Disagree □Strongly disagree

17. Most bike lanes in my city are available for use.

□ Strongly Agree □Agree □Neutral □Disagree □Strongly disagree

18. Bike parking facilities in my city are available and convenient.

□ Strongly Agree □Agree □Neutral □Disagree □Strongly disagree

19. The fares of bike parking in my city are reasonable.

□ Strongly Agree □Agree □Neutral □Disagree □Strongly disagree

20. Biking is good for people's health.

□ Strongly Agree □Agree □Neutral □Disagree □Strongly disagree

21. Bicycle is the among lowest emitter of greenhouse gas in all modes of transport.

□ Strongly Agree □Agree □Neutral □Disagree □Strongly disagree

22. In general there are too many cars on the road and the government do something to reduce driving.

□ Strongly Agree □Agree □Neutral □Disagree □Strongly disagree

23. Speed is a very important aspect when choosing the mode of travel.

□ Strongly Agree □Agree □Neutral □Disagree □Strongly disagree

24. Safety is a very important aspect when choosing the mode of travel.

□ Strongly Agree □Agree □Neutral □Disagree □Strongly disagree

25. Bicycle is a part of Chinese traditional culture.

□ Strongly Agree □Agree □Neutral □Disagree □Strongly disagree

26. Bicycle is a symbol of modern society.

□ Strongly Agree □Agree □Neutral □Disagree □Strongly disagree

# Appendix C. Survey Questionnaire in Chinese

1. 请选择您的性别：
   □男 □女
2. 请选择您的年龄段：
   □ 19 岁 – 30 岁 □ 31 岁 – 50 岁 □ 51 岁以上

3. 请选择您的家庭月收入水平：
   □ 800 元以下 □801 元-1500 元 □4501 元-9000 元
   □9001 元-35,000 元 □ 35,000 元以上

4. 请选择您的所在城市：
   □北京 □上海 □广州 □其他：_____。

5. 您家是否有自行车？
   □是 □否

6. 您是否使用公共自行车？
   □是 □否 □您所在城市没有公共自行车

7. 您经常使用的交通方式有哪些？（多选）
   □小汽车 □公共交通（公交、地铁、BRT □自行车 □电动车 □步行 □出租车 □其他

8. 您使用自行车出行的频率如何？
   □ 平均每周 1-2 天 □平均每周 3-4 天 □平均每周 5 天以上 □您不常使用自行车出行

9. 您选择自行车出行的主要目的有哪些？（多选）
   □上下班、上下学 □买菜、购物 □健身 □娱乐休闲 □其他 □您不常使用自行车出行

10. 与前些年相比，您在过去的一年中使用自行车的频率：
    □更少 □无明显变化 □更多

11. 若自行车出行环境得到改善，您是否会更多选择使用自行车？
    □是 □否

12. 您家距离您工作单位（或学校）大约有多远？
    □小于 3 公里 □3-7 公里 □7-10 公里 □大于 10 公里

13. 您家距离最近的超市大约有多远？
    □小于 3 公里 □3-7 公里 □7-10 公里 □大于 10 公里

14. 您是否有小汽车？

☐是 ☐否

15. 您认为小汽车对空气污染的影响有多严重？

☐ 几乎没有影响 ☐有一定影响但影响有限 ☐影响适中 ☐影响较大 ☐影响很大

针对下列陈述请给出您的观点：

16. 您所在的城市有较完善的自行车道。

☐十分同意 ☐同意 ☐中立 ☐不同意 ☐十分不同意

17. 您所在城市的自行车道被小汽车占用的情况较少。

☐十分同意 ☐同意 ☐中立 ☐不同意 ☐十分不同意

18. 您所在的城市有足够的自行车停车设施且使用便捷。

☐十分同意 ☐同意 ☐中立 ☐不同意 ☐十分不同意

19. 您所在的城市的自行车停车设施价格合理。

☐十分同意 ☐同意 ☐中立 ☐不同意 ☐十分不同意

20. 骑车对健康有益。

☐十分同意 ☐同意 ☐中立 ☐不同意 ☐十分不同意

21. 骑车产生的温室气体排放最少的交通方式之一。

☐十分同意 ☐同意 ☐中立 ☐不同意 ☐十分不同意

22. 目前小汽车数量过多，政府应该进行干预以减少小汽车出行。

☐十分同意 ☐同意 ☐中立 ☐不同意 ☐十分不同意

23. 在选择出行方式时，速度是一个重要的考虑。

☐十分同意 ☐同意 ☐中立 ☐不同意 ☐十分不同意

24. 在选择出行方式时，安全是一个重要的考虑。

☐十分同意 ☐同意 ☐中立 ☐不同意 ☐十分不同意

25. 自行车是中国传统文化的一部分。

☐十分同意 ☐同意 ☐中立 ☐不同意 ☐十分不同意

26. 自行车是现代社会的象征。

☐十分同意 ☐同意 ☐中立 ☐不同意 ☐十分不同意

# Appendix D. R code for Data Modeling

Bicycle Ownership:

```
glm(formula = BikeOwn~ City + Gender + Age + Income + AutoOwn + DistanceHome +DistanceMarket+ AutoAir +BikeLane + LaneOccupy+BikeParking + ParkPrice + BikeHealth + BikeEmission + AutoOverNum + TravelSpeed + BikeTradition + BikeModern, family = "binomial", data=data);
glm(formula = BikeOwn~ City  + Age + Income + AutoOwn + DistanceHome +DistanceMarket+ LaneOccupy+ ParkPrice  + BikeEmission + AutoOverNum + TravelSpeed + BikeTradition , family = "binomial", data=data);
```

Bicycle Use:

```
glm(formula = Biker ~ City + Gender + Age + Income + AutoOwn + DistanceHome +DistanceMarket+ AutoAir +BikeLane + LaneOccupy+BikeParking + ParkPrice + BikeHealth + BikeEmission + AutoOverNum + TravelSpeed, family = "binomial", data=data);
glm(formula = Biker ~ City + Gender + Income + AutoOwn + DistanceHome+ AutoAir + ParkPrice + BikeHealth + AutoOverNum + TravelSpeed, family = "binomial", data=data);
```

Bicycling Frequency:

```
glm(formula = Frequency_Morethan3 ~ City + Gender + Age + Income + BikePurpose_1 + BikePurpose_2 + BikePurpose_3 + BikePurpose_4 + BikePurpose_5 + AutoOwn + DistanceHome + DistanceMarket + AutoAir + BikeLane + LaneOccupy + BikeParking + ParkPrice + BikeHealth + BikeEmission + AutoOverNum + TravelSpeed, family = "binomial",
data = data_bikers);
glm(formula = Frequency_Morethan3 ~ Gender + Age + Income + BikePurpose_1 + BikePurpose_2 + DistanceHome + DistanceMarket + TravelSpeed, family = "binomial", data = data);
```

Propensities to Bike in the Future:

```
glm(formula = BikeFuture ~ City + Gender + Age + Income + FreqChange + Frequency + AutoOwn + DistanceHome + DistanceMarket + AutoAir + BikeLane + LaneOccupy + BikeParking + ParkPrice + BikeHealth + BikeEmission + AutoOverNum + TravelSpeed + BikeTradition + BikeModern, family = "binomial", data = data_all);
glm(formula = BikeFuture ~ City + Gender + Age + Frequency +
      DistanceMarket + LaneOccupy + BikeHealth + AutoOverNum +
      TravelSpeed + BikeTradition, family = "binomial", data = data_all)
```