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Free-Floating Bike Sharing in Jiangsu: Users' Behaviors and Influencing Factors

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Abstract: In order to explore the factors affecting users' behaviors in a free-floating bike sharing (FFBS) system in China, a survey was conducted in Jiangsu province, China in 2017, and the travel characteristics of FFBS users were analyzed. A binary logistic model was applied to quantify the impact of various variables regarding residents' usage preference based on 30401 valid questionnaires. The findings show that (1) FFBS was mainly used for short-distance travel in cities, especially for commuting and schooling, and the time period of travel in FFBS coincided with the rush-hour in urban areas; (2) a higher level of education, a higher daily transportation cost, the convenience of picking up and parking, and the contribution to users' health could promote the usage of FFBS, while malfunctioning bicycles and limited regulations were major obstacles restricting the development of FFBS; (3) interestingly, people with high-incomes rather than those with low-incomes showed an inclination for FFBS owing to the charge mode. This research provides empirical evidence to facilitate the formulation of urban transportation policies and to improve the management of FFBS for the operators.

Keywords: free-floating bike sharing; travel behavior; influencing factors; China

1. Introduction

In recent decades, urban public transport policies have paid more attention to public health, traffic congestion alleviation, energy saving and emission reduction [1]. With the rapid development of the internet and smartphone technology, mobile payment has become increasingly prevalent. Consequently, free-floating bike sharing (FFBS) systems have been widely adopted in major cities across mainland China.

Cycling, in general, has numerous benefits, such as the prevention of various diseases, traffic congestion reduction, zero CO_2 emissions and convenient parking by providing alternatives to auto-commuting and increasing the usage of public transit [2]. Also, it can provide an attractive solution for the "first and last-mile" problems in multimodal transports [3]. However, China has experienced a tremendous decline of bike use nationwide since the 1980s [4]. Although some cities have introduced public bike schemes since 2008, the bike has not restored its position until the mass of FFBS schemes which have been implemented since 2016.

FFBS is a dockless bike sharing service provided by enterprises in various places, such as campuses, subway stations, bus stations, residential areas, commercial areas, and public service areas. It operates using a time-sharing leasing mode and is essentially a new type of bike rental business, one where the customer can make a rental payment via mobile phone. It can increase the use of bicycles in transit and maximize the utilization rate of public roads.

Although FFBS is a bike sharing system, there are several features that distinguish FFBS from traditional bike sharing systems: (a) FFBS is a bicycle sharing service without a dock and bikes can be locked and returned at any open space in the city, thereby eliminating the need for specific stations [5]; (b) FFBS is operated as a time-sharing leasing mode and all urban residents can utilize it by phone, not only those residents who hold IC cards; thus, user satisfaction and loyalty are greatly improved [6]. In addition, FFBS is equipped with a GPS device which records the location of the bike in real time; as a result, the risk of bikes being stolen is low.

The Chinese government explicitly states that green travel must be encouraged to achieve energy savings and emission reductions. As a low-carbon mode of transport, FFBS has been promoted and developed rapidly in many large and medium-sized Chinese cities. Therefore, the Chinese government supports these systems as a more sustainable mode of transport for short trips. However, the market and the government are not adequately prepared for its extensive spread and even lack corresponding policies. With the rapid development of FFBS, many problems have been exposed, such as an irrational distribution of FFBS schemes, untimely maintenance of bikes and a lack of regulations on parking and recycling. In addition, arbitrary parking not only wastes transport resources but also negatively impacts the management of urban traffic [7]. These problems will directly influence the loyalty and the frequency of FFBS users. Although the number of shared bikes is still increasing and it is becoming easier for residents to find bikes, many FFBS users are abandoning the service and losing interest.

To improve bike utilization and user satisfaction, it is important to conduct research to better understand the characteristics of FFBS use and residents' usage preferences. Firstly, the travel characteristics of FFBS were analyzed. Then, we chose respondent attributes, travel demand and the attitudes as influential variables, and a binary logit model was applied to explore the influencing factors of FFBS use. The results can provide suggestions for operators to promote their FFBS service as well as important evidence for policy-makers to better regulate FFBS. This study contributes to identifying current barriers to FFBS and the shortcomings of the operational process. Specifically, the analysis focuses on behavioral considerations such as factors underlying the adoption of FFBS. According to the research of this paper, the related policy changes for FFBS can be made by the government and enterprises, which could promote the usage of FFBS and attract more residents to use this sustainable mode of transport.

Following this introduction section, Section 2 reviews the relevant literature on bike sharing systems and FFBS, although it should be noted that the latter was mainly limited to Chinese articles. Section 3 offers an overview of FFBS in China, including its emergence, development and current policies. Section 4 describes the research methods. Based on data analysis, Section 5 explains the characteristics of FFBS use in Jiangsu Province. Section 6 presents the model and findings, and lastly, Section 7 concludes the research.

2. Literature Review

The fast development of third generation bike sharing systems in Europe has attracted a lot of interest from scholars over the past decade. Since 2016, FFBS has begun to spring up in China as a new bike sharing system which relies on the growing use of internet and smartphones; few studies have explored this issue. The literature review focuses on previous studies on bike sharing systems and the limited research of FFBS.

2.1. User Characteristics of Bike Sharing

The user characteristics played an important role in the bike sharing system; much research focuses on the differences between different user groups, such as users and non-users, membership card holders and non-card holders, private bike users and public bike users. Fuller et al. [8] conducted a survey of the largest bike sharing program in Montreal, Canada. The sample consisted of 2502 respondents and the regression results showed that those who lived near docking stations and younger people are more likely to use bike sharing systems. Also, the results also implied that regular bike sharing users are usually those who received a high school diploma or above. Buck et al. [9] found that public bikes attract more female users. The results also revealed a connection between public bike use and poverty since poorer people and those who do not own a car or a bike are more likely to use public bikes. Fishman et al. [10] studied the difference between bike sharing users and non-users in Melbourne and Brisbane. The results revealed that most of the users work in locations concentrated in the city center; however, residential and work locations of non-users are heavily dispersed. Membership card holders usually use bike sharing for commuting, while the purpose for non-member users varies [11]. Lathia [12] showed that allowing daily users to use the system could result in an increased bike sharing usage on weekends and overall usage increases at a number of stations. Guzman et al. [13] compared public bike users and non-users in Hangzhou city, China, and suggested that the number of public bikes, the quality of public bikes, the maintenance of bikes and the extension of operation time are all important factors affecting the satisfaction of public bike users.

2.2. Preference of Bike Sharing

With the spread of bike sharing schemes across the world, public preference has become another important issue in this field. Manaugh et al. [1] analyzed the influence of different bike sharing stations (residential buildings, commercial buildings, parks, schools and subway stations) on their use and found that commercial buildings help to increase shared bike usage more than residential buildings, while parks help to increase shared bike usage three to five times more than schools or subway stations. Bachand-Marleau et al. [14] studied the factors that affect the use of bike sharing in Australia and the UK. The results showed that private bikes were difficult to park and they were vulnerable to theft, and the convenience of using advanced public facilities attracted people to use bike sharing. Yang and Long [15] established a binary logit model based on 520 questionnaires to explore the factors influencing users' willingness to adopt bike sharing, and the model showed that the users' environmental responsibility, the public transport improvement as well as the users' attention to healthy living had a positive impact, while the users' consciousness of environmental crisis had a negative impact. Moreover, researchers have found that population density and land use were important factors influencing the use of bike sharing. El-Assi et al. [16] showed that public bike users were more likely to be attracted to areas with high employment density, which implied that a large number of users used bike sharing for commuting. Besides this, the Central Business District (CBD) was a region with high population density and high employment density; according to Buck et al. [17], the distance from the public bike station to the CBD was negatively related to passenger flow, indicating that CBD was a more frequent travel area for public bikes. Furthermore, evidence showed that a more comfortable travel environment could encourage people to use shared bikes and vice versa [11,18,19]. Cui et al. [20] studied how land use and the buildings in the environment influenced bike ridership. The results showed that retail and recreation centers had a positive effect on bike ridership.

2.3. Limited Research on FFBS

To some extent, FFBS is different from traditional bike sharing systems, and it emerged in China in 2016. Compared to traditional bike-sharing schemes, only a few international publications have addressed this issue, although recently there have been some Chinese articles that have shed light on this topic [7]. Deng et al. [21] found that FFBS use in Beijing showed an obvious rush hour characteristic on workdays and it was affected by public transportation, trade, dining and so on. Jiang et al. [22] analysed the influence of FFBS on college students, and results showed that college students travelled more frequently as free-floating bicycle coverage increased, while their willingness to buy a private bicycle decreased. Furthermore, some studies addressed the redistribution optimization of FFBS. Liu et al. [23] adopted the cost–benefit theory and found that FFBS helped to improve bicycle travel, optimized traffic structures and achieved energy-savings and emission-reductions, while it also caused some problems, such as the occupancy of road resources, hindrances because of disorderly parking and so on. Therefore, some studies optimized the free-floating bicycle distribution to improve the

FFBS's usage. Based on the global positioning system (GPS) data of an FFBS in Munich, Reiss et al. [24] identified the different mobility patterns of FFBS users and then established a demand model to optimize the distribution of bikes within the operating area, taking into consideration the weather conditions, time of the day and holidays/weekends. Pal et al. [3] developed a "hybrid nested large neighbourhood search with variable neighbourhood descent algorithm" to solve the static rebalancing problems for both FFBS and public bicycles. Caggiani et al. [25] aimed to optimize the FFBS allocation through test and real cases, according to spatial and social equity principles as well as the relationship of the toll amount, the days after policy applied and the pursued equity.

Effective policy is one of the prerequisites to promoting active travel modes. In many European cities, an effort has been made to encourage active travel modes including promoting facilities such as cycle lanes, education, appropriate land use planning and policies which constrain car ownership and car use [26–28]. Although China is still one of the top countries in terms of number of cyclists, bikes are always considered inferior to cars. Despite the fact that most Chinese cities have a strategy for being a sustainable or livable city, few policies or regulations effectively promote bike use. In the face of a new model combining the Internet and the bike, the Chinese government is still short of a perfect policy for FFBS; this will greatly obstruct the development of FFBS.

Based on an existing literature review, there is no doubt that analysis of users' willingness is necessary for the priority development of FFBS. However, there are many differences between public bicycles and FFBS, such as the use of a parking station, lease mode, operation mode and even the users; therefore, it is worthwhile to explore to what extent the operational experience of public bicycles can be applied to FFBS. In order to provide a better service and loyalty for FFBS users, this paper analyses the characteristics and influencing factors of FFBS adoption based on a survey of around 30,000 participants.

3. An Overview of Bike Sharing in China

3.1. The Development of Bike Sharing

Since Uber entered the Chinese market, Chinese people have been increasingly aware of the sharing economy. A great leap forward for the sharing economy took place in 2014 when its growth rate exceeded 118.5%. Although the growth rate has slowed down, the industry size of the sharing economy exceeded two trillion Yuan (317 billion dollars) in 2015 [29]. Among them, transport-related sharing economy apps have been one of the biggest contributors of the sharing economy and 26.7 million Chinese people have reaped the benefits of shared transport in 2015 [29]; thus, a large market of shared transport has been cultivated.

The boom in bike sharing systems can be traced back to 2008 when public bike schemes were first introduced in Hangzhou and Beijing. Because of the demonstration effect of public policies implemented in Beijing, public bike schemes were then piloted in more than a hundred Chinese cities not long afterward. By the end of 2014, 220 cities had implemented public bike schemes [29]. However, the development and actual effectiveness of public bike schemes are highly imbalanced because they depend on how local authorities have recognized the issue and in which way local authorities have implemented the scheme. Most of the public bike schemes rely on government subsidies to maintain operations [30]. Even the most successful Hangzhou scheme can only break even through the licensing of their business model and advertisements [13]. The stubbornly high cost of maintaining public bike schemes persistently increases the government's financial burden; therefore, bike sharing companies such as Ofo and Mobike have arisen in response to this opportune time (shown in Figure 1).

Constrained by the distribution of docking stations, public bikes cannot effectively be used for short trips in most cities. Since 2016, FFBS has rapidly obtained more users than traditional bike sharing schemes because of its convenience. More than 70 bike sharing companies are operating more than 16 million bikes, and the total amount of registered users exceeded 130 million by July 2017 [31]. The number of users of the top two bike sharing companies was 7.69 million and 3.69 million, respectively, by February 2017 [32]. By the end of February 2017, the amount of Mobike users was 2.5 times that in October 2016. Similarly, the average daily time spent on the Mobike app increased from 4.7 million minutes in October 2016 to 10.9 million minutes in February 2017.

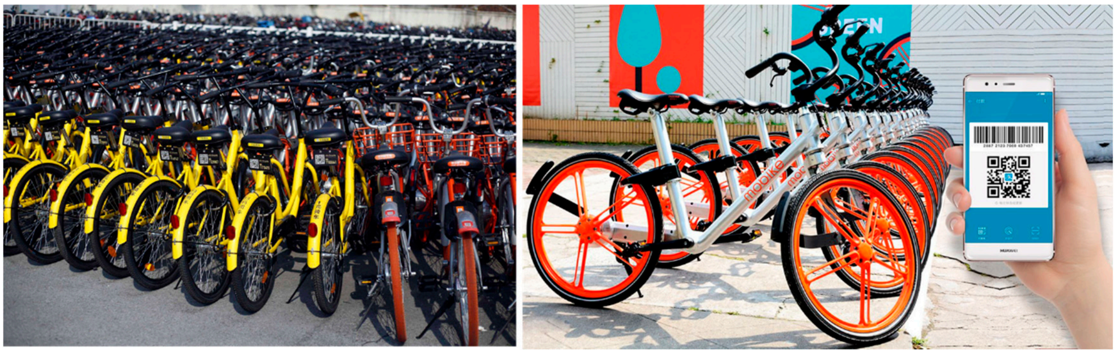

Figure 1. Free-floating bike sharing (FFBS).

There are many participants in the market, such as Mobike, Ofo, and U-bicycle, applying different marketing strategies and using different bikes and locks. Therefore, even though the rapid expansion of FFBS implies a high acceptance of FFBS in general, the actual user experience highly depends on the particular service they have chosen. Moreover, their experience may vary depending on where they use bike sharing because local authorities have different policies towards bike sharing schemes.

In the meantime, problems caused by shared bikes have been widely reported, especially after the third biggest bike sharing company Bluegogo went bankrupt in late 2017 [33–35]. Pedestrians are very much influenced since randomly parked bikes dominate sidewalks. Wrecked bikes may not be properly recycled and reused. All of these issues require government intervention.

3.2. Policies on FFBS in China

The development of public bikes can fall into three successive phases: (a) government-oriented, (b) company-built and government-operated; and (c) government-invested and company-operated. In the beginning, all stages of public bike schemes, including planning, construction, and operation are dominated by local authorities. However, the construction speed and the operational efficiency of public bike systems adopted in other cities were severely restrained because of technical barriers. Meantime, professional companies had already been established to help local authorities design and build the systems. Thus, local authorities were only responsible for operation and management at this stage. Later, local authorities were only in charge of approving and initiating the project, which was then built and operated by professional companies. There is clear evidence that local governments have delegated power to the market to avoid involvement in the complicated and financially burdensome public bike system.

Unlike public bike schemes, FFBS have hardly been constrained by the government until 2017, when more and more local authorities found that disorderly shared bikes had become increasingly intolerable. On 3 August 2017, the Guiding Opinions on Encouraging and Regulating the Development of Internet Bike Rental was issued by the Ministry of Transport and nine other ministries [34]. The Guiding Opinion explicitly points out that parking spots should be regulated. Also, it highlights the importance of strengthening the supervision and control of FFBS at all stages. Later, on 6 November 2017, the China Communication Industry Association officially released the General Technical Requirement of IOT Based Bike Sharing Systems, further regulating the use of shared bikes and bike sharing apps [36]. In addition, more specific local guidance on encouraging and regulating the development of FFBS has been issued in Shanghai, Hangzhou, Nanjing, Chengdu, and Shenzhen.

It is indubitable that understanding FFBS use and the attitudes towards FFBS is essential for both operators and the government. This paper attempts to analyze the characteristics and influencing factors of the adoption of FFBS. Based on a survey of 30,000 respondents, the results could help FFBS operators to provide service more accurately, as well as providing first-hand information for policy-makers to better regulate the market.

4. Research Methods

4.1. Questionnaire Design

As this is the first attempt to study FFBS use in China, the questionnaire starts with travel demands, travel behaviors and FFBS use experience. Attitudes towards FFBS are investigated next. The main contents of the questionnaire include three aspects: demographic attributes of travelers including gender, age, educational level, income level, residential area, occupation, and public bike membership; the travel demand and travel behavior including travel distance, travel cost, travel mode, travel purpose, and riding time; FFBS use experience including FFBS use frequency, average travel time, FFBS's impact on car use, FFBS's impact on the use of public transport, and problems operators have met; attitudes towards shared bikes, including awareness of bike sharing, shared bike use in residential areas, service fee, whether free-floating bicycles are hard to find, advantages of FFBS, its benefits for the society as a whole, and barriers to using FFBS.

As shown in Figure 2, this research consists of four steps, which are research design, data collection and analysis, model explanation, and variables identification. Firstly, the research was designed according to the operation experience and problems encountered in the actual operation of FFBS. Secondly, the case sites and research methods were selected based on the cities with FFBS operation in Jiangsu. Thirdly, the independent variable and the dependent variable were defined, and the binary logistic model was established. Lastly, the regression analysis was conducted in SPSS, the influencing factors were identified, and the model was tested according to the parameters.

4.2. Case Site

Jiangsu was selected as the case for this study because it is a leader in adopting innovative technologies and new policies, and FFBS has been widely adopted in this area. The research results could provide the evidence and reference to other regions where FFBS has not yet introduced. Additionally, Jiangsu, as an important part of the Yangtze River Delta region, is located in the middle of the eastern coastal areas of China, with a permanent population of about 80 million and 8.59 trillion Yuan (13,615 billion dollars) [37] of GDP achieved as of 2017. Early in 2017, Nanjing, Wuxi, Suzhou, Yangzhou, Changzhou and Xuzhou, as relatively economically developed areas in Jiangsu, started the rise of FFBS. The rest of the cities had no FFBS market operation, owing to the impact of local government interventions and economic factors; therefore, these above cities were chosen as study areas, as shown in Figure 3.

A random sample survey was conducted in six major cities, and the style of the survey included an online survey and hard copy survey. The survey was conducted from 27 May to 10 June 2017 by the School of Transportation, Southeast University. The online survey was conducted through social media, such as QQ and WeChat, while the face to face interviews were carried out at subway stations, commercial areas, schools, bus stops and city parks during daytimes (7:30–12:30, 13:30–16:00, 17:00–21:00). A total of 31,669 questionnaires were collected, of which 30,401 questionnaires were valid. The number of valid questionnaires through offline and online surveys is 1275 and 29,126, respectively. The proportion of valid questionnaires from each surveyed city is as follows: 29.93% (9100) in Nanjing, 22.57% (6861) in Suzhou, 17.97% (5462) in Changzhou, 13.32% (4050) in Wuxi, 8.47% (2576) in Yangzhou, and 7.74% (2352) in Xuzhou. The disproportionate number of questionnaires collected in Nanjing and Suzhou is due to the better local economic conditions and larger population sizes; with more netizens in these two cities, more online surveys were filled out. The descriptive results revealed that the characteristics of FFBS users are similar across the six surveyed cities. Moreover, there is normally little difference between cities in terms of transport policies in China, because these policies are often introduced by the central or provincial governments and the city government merely implements them. Therefore, in the analysis, we take Jiangsu province as the case.

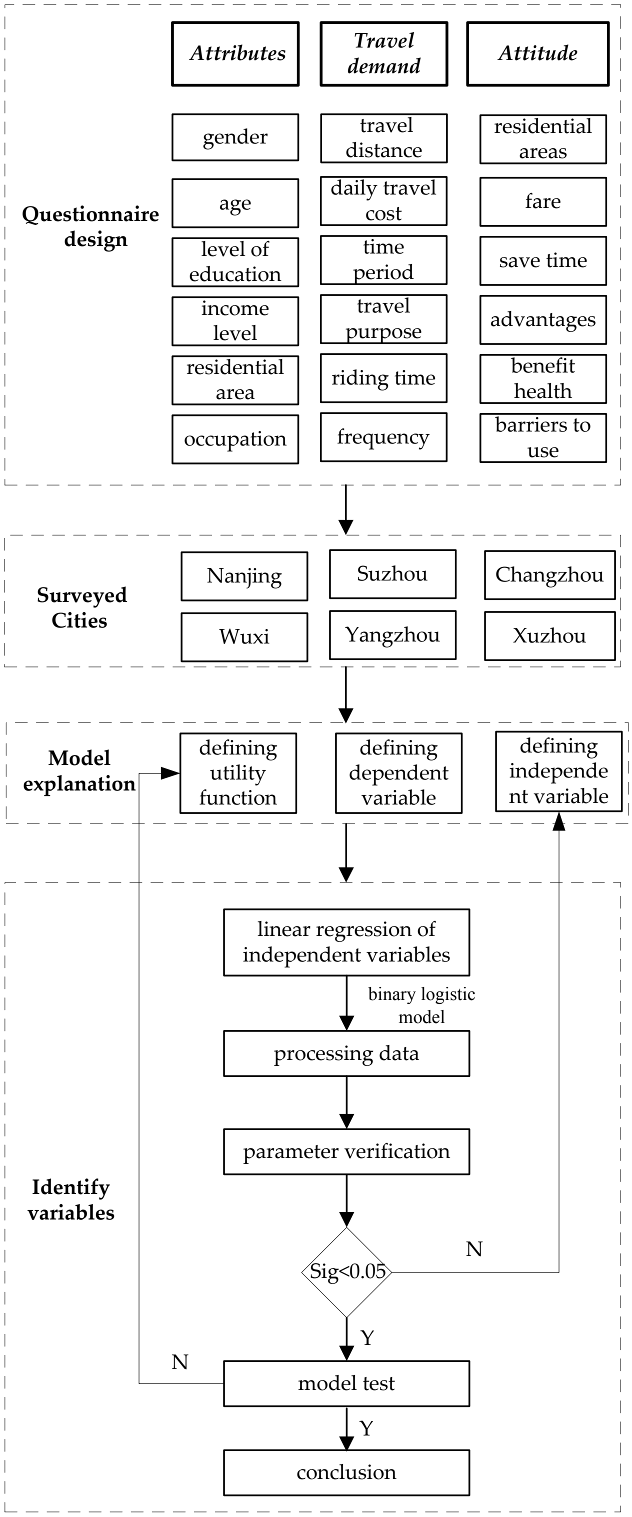

Figure 2. Research outline.

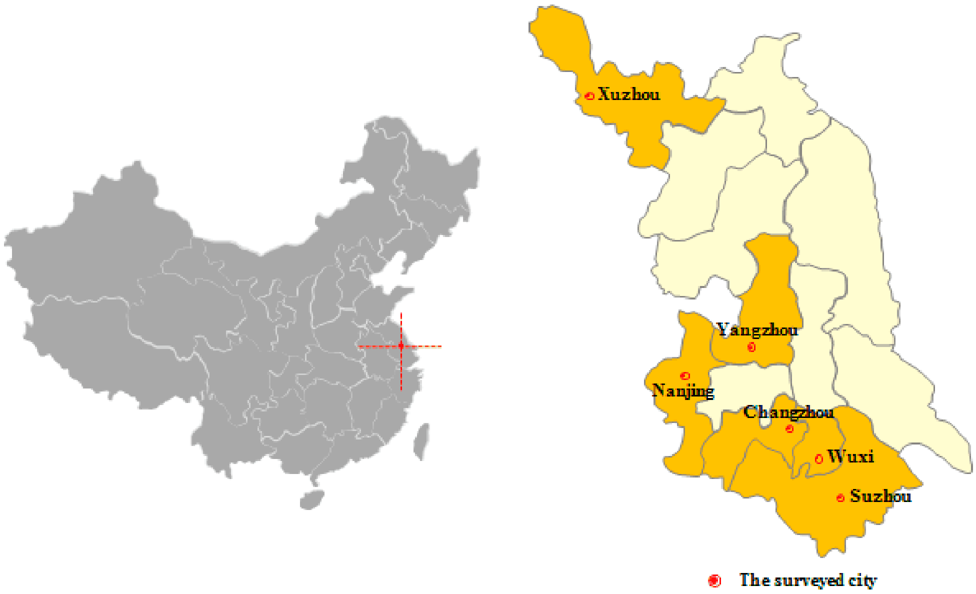

Figure 3. Surveyed cities in Jiangsu Province.

4.3. Demographic Information of the Sample

The demographic information of the sample is shown in Table 1. It shows that the proportion of male respondents is slightly higher than average, but the difference is acceptable. In terms of the age, most of the respondents are in the 19–40 years-of-age groups. These people are mainly college students or young professionals. Because they are frequent internet users, it is easier for them to respond to an online survey compared to other age groups. Since the proportion of younger people in the sample is significantly higher than the reference value, the results may not be able to reflect the attitudes of elder people who do not use FFBS. This is definitely a limitation of this study, because those who do not use FFBS are also influenced by the problems caused by FFBS, such as disorderly parked bikes. The distribution of income level is mainly concentrated at less than 50,000 Yuan (7922 dollars) and 60–120,000 Yuan (9507 dollars–19,014 dollars); in particular, the population with an income of 60–120,000 Yuan (9507 dollars–19,014 dollars) accounts for nearly half of all the samples. For this part of the population, it is difficult to afford to buy cars in the short term. In terms of occupations, the majority are students, employees, and public functionaries, accounting for 70.7%. This is in line with the results of the survey in North American cities: in the questionnaire survey of public bikes, interviewees were mainly commuters and students [2]. The educational level is mainly concentrated in the undergraduate level; this part of the population is more aware of mobile payments and is more likely to accept new technologies.

Table 1. Demographic information of the sample.

Items		Proportion/% (Sample)
Gender	Males	52.7
	Females	47.3
Age	≤18	12.3
	19–40	74.7
	41–65	9.4
	≥66	3.9
Income level (10 thousand CNY/year)	≤5	30.2
	6–12	48.5
	12–20	14.7
	>20	6.6

Table 1. *Cont.*

Items		Proportion/% (Sample)
Occupation	Student	36.9
	Teacher	7.3
	Employee	20.5
	Public functionary	13.3
	Worker	9
	Doctor	2.7
	Retired	2.4
	Others	7.9
Education level	Below high school	2.2
	High school	20.8
	Undergraduate	55.9
	Postgraduate	21.1

5. Characteristics of FFBS Use in Jiangsu Province

5.1. Distribution of Travel Purpose

As shown in Figure 4, 57.36% and 22.76% of respondents expressed that commuting and attending school are the main purposes of FFBS. Additionally, FFBS is adopted to fulfill citizens' travel demands for living, and the ratios of using FFBS for sports and shopping add up to 7.59% and 3.47%. Besides this, FFBS is also adopted for transfer, and the ratio is 4.26%. These characteristics indicate that FFBS plays an important role in the urban transport system, especially in solving the rigid demand. It also implies that FFBS could alleviate traffic pressure during the rush hour to a certain extent.

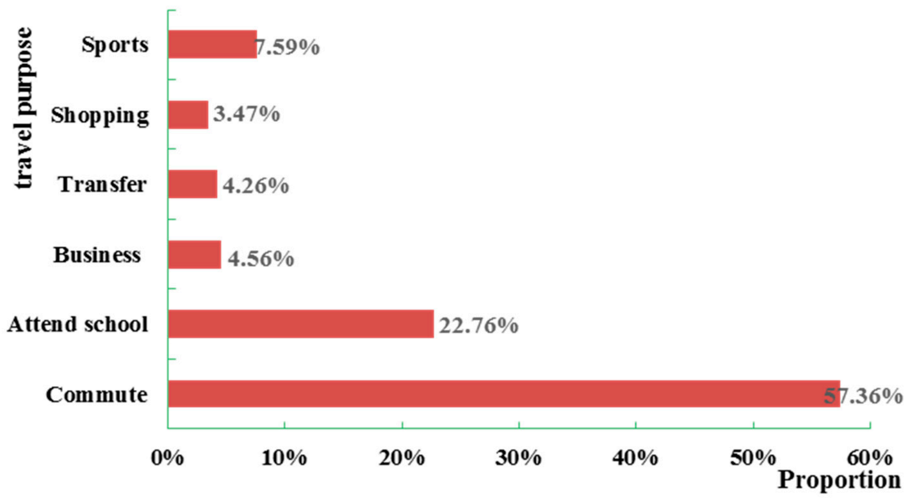

Figure 4. Travel purposes.

5.2. Time Period of Travel for FFBS

In terms of the time period of travel of FFBS users, the distribution shows three peaks, which are consistent with transport peaks in the city: they are 7:00 to 9:00 (morning peak), 11:00 to 13:00 (afternoon peak) and 17:00 to 19:00 (evening peak), as shown in Figure 5. The peaks for different travel purposes are different and are consistent with citizen's travel demands. The peaks for attending school and commuting are especially obvious due to the strict time requirements of schools and companies. However, the peaks for shopping and sports are in the morning and evening, while the peak for business is in the afternoon. Especially with regard to attending school and commuting, this phenomenon is obvious, as it correlates to the opening hours of schools and companies. As for sports, the using time of FFBS is mainly concentrated in the morning between 6–8 a.m. Shopping is dominated by the morning peak and the evening peak, while business is mainly concentrated in the afternoon peak. Therefore, the urban traffic management departments should strengthen law enforcement and management in these three peaks. At the same time, FFBS enterprises also need to perform operation management and scheduling during these three periods so that the FFBS can meet users' travel demands.

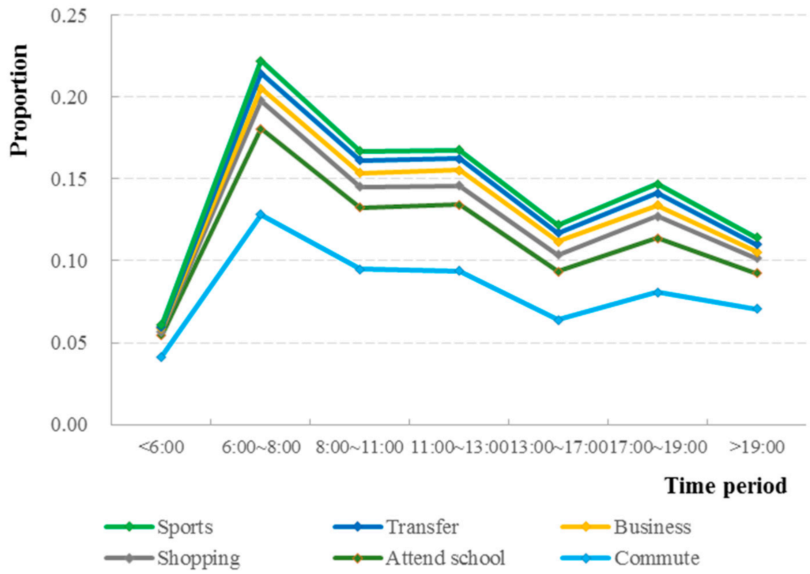

Figure 5. Time period of travel for FFBS.

5.3. Travel Distance of FFBS

As for the structure of the travel distance of FFBS users, we find that FFBS is rather prevalent in short-distance travel as the proportion of use of FFBS in a trip between 0–4 km is 67.7% (0–2 km is 31.1%, 2–4 km is 36.6%), as shown in Figure 6. By contrast, the proportion of use of FFBS in a trip above 4km is 32.2%. This implies that FFBS is an important mode of transportation to solve the "first and last mile" in the city, such as going to railway stations, bus stations and so on.

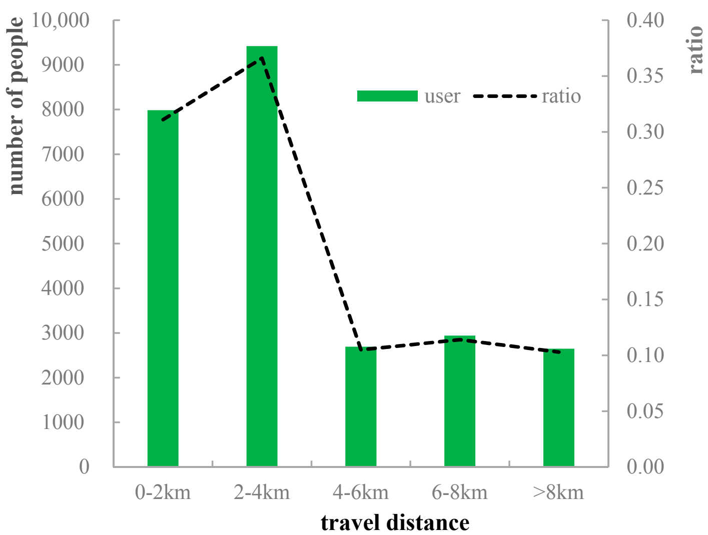

Figure 6. Travel distance and ratio.

5.4. Daily Use Frequency

As shown in Figure 7, the ratio of use of FFBS only once a day is very small, accounting for about 5%; by comparison, the travel frequency of a majority of users is three times and above, which represents 82.74% of respondents. This finding is in line with the data from the Velib system operator, JCDecaux, that their bikes are used four times a day [38]. The number of daily trips per capita in Jiangsu Province is 6.4, which suggests that FFBS has begun to be adopted by urban residents and it is not only a temporary supplement to other modes of transport, but also an important basic urban transport tool.

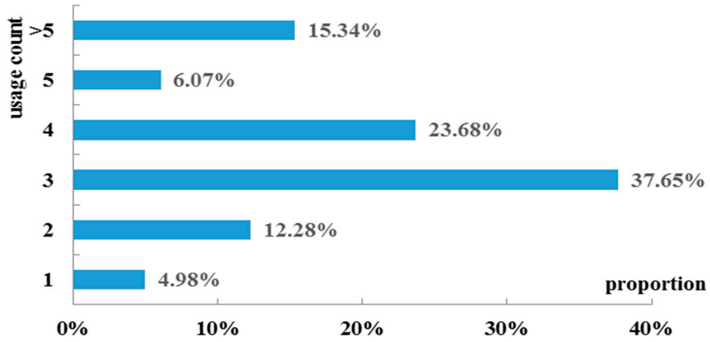

Figure 7. Use frequency.

5.5. Space Demand of FFBS

The starting point of the travel for FFBS can be seen as its demand point. Taking Nanjing city as an example, the demand area of FFBS is analyzed by means of thermal chart distribution based on the GPS data provided by the company Bluegogo. As shown in Figures 8 and 9, the spatial demand of weekdays and weekends can be found. Shared bikes are frequently used in the city center, and a gradual decline from the city center to the suburban districts of the city is presented, and weekdays and weekends are less differentiated. Compared with the weekdays, the frequency of FFBS use at weekends increased only in Gulou District. Since there are many colleges and universities in Gulou District (city center), a major group of FFBS users, students improved FFBS use at weekends.

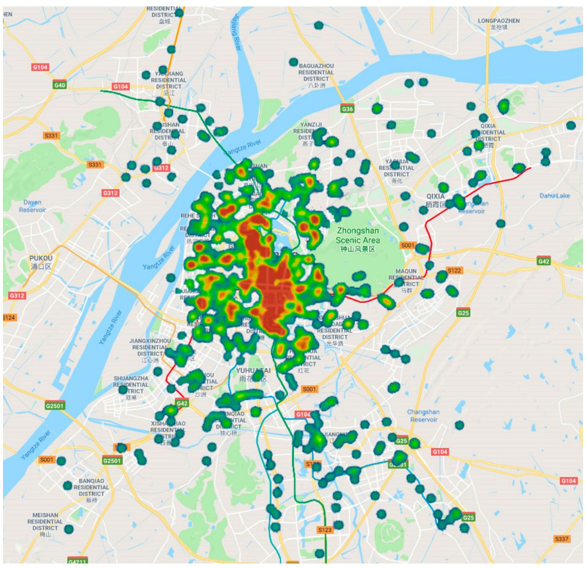

Figure 8. Spatial distribution of FFBS on week days.

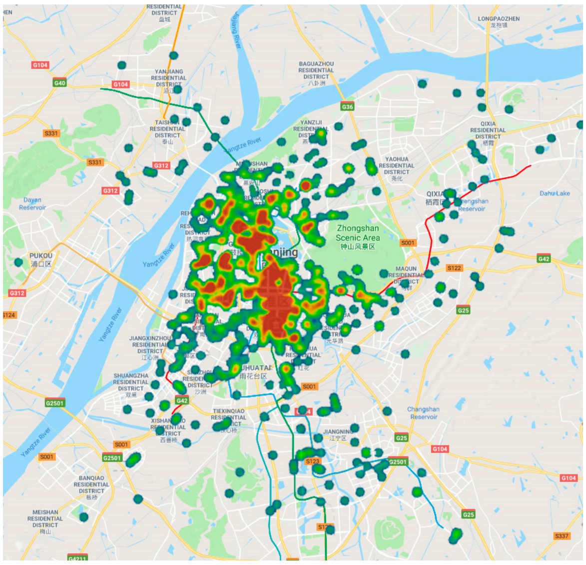

Figure 9. Spatial distribution of FFBS at the weekends.

6. Model and Results

6.1. Model Explanation

McFadden studied the discrete choice based on the random utility theory and it can be expressed as follows: under specific conditions, the traveler selects the maximization of utility [39]. The binary logit model is very effective in analyzing two classification problems; that is, the choice set only contains two alternatives. A binary logit model may be derived within a random utility framework and it can be written as

$$U_{in} = X_{ink}\theta_k + \varepsilon_{in} \tag{1}$$

where ε_{in} is a random error term; due to the analysts' imperfect knowledge, unobserved attributes, unobserved taste variations, measurement errors often exist, and random utility can represent the impact of the uncertain factors. X_{ink} is the set of independent variables/regressors that is known by the modeler and represented by a function of the vector of alternative attributes. θ_k is a vector of unknown parameters. i represents the i_{th} alternative choice, n represents the n_{th} user, k represents the k_{th} independent variable.

The random term in the Equation (1) obeys the double exponential distribution, and the probability that the individual n will choose alternative choice i can be written as

$$P_{\text{in}} = \frac{e^{\theta_k X_{ink}}}{\sum\limits_{i=1}^{N} e^{\theta_k X_{ink}}} \tag{2}$$

where P_{in} equals the probability that a person n with characteristics X_{ink} chooses i_{th} choice [40], i = 1, 2.

When the above model is estimated, the decision variable is defined.

$$\ln \frac{P_{2n}}{P_{1n}} = a + \theta_1 X_{1n} + \ldots + \theta_k X_{kn} \tag{3}$$

where P_{2n}/P_{1n} is the ratio of the probability for two selected choices. P_{1n} is taken as the selection probability of the reference category and the selection probability of the other category P_{2n} is compared with it.

6.2. Variable Definite

As mentioned above, the usage of FFBS is influenced by citizens' basic attributes, travel characteristics and attitudes to FFBS. Thus, all of these factors are taken as the independent variables to analyze the city residents' preference for FFBS usage, as shown in Table 2. In this paper, whether the respondent has used FFBS or not was taken as the dependent variable, and 1 denotes that the user selects to use FFBS while 0 denotes that they do not. As the dependent variable is binary, a binary logit model is established based on these variables by statistical product and service solutions (SPSS).

Table 2. The variables chosen to analyze the citizens' preference on FFBS usage.

Items	Variable	Definition and Notes
Basic attribute	Gender	Males = 1 females = 2
	Age	(0, 18] = 1 (18~40] = 2 (41~65] = 3 above 65 = 4
	Occupation	Student = 1 Teacher = 2 Employee = 3 Public functionary = 4 Worker = 5 Doctor = 6 Retired = 7 Others = 8
	Level of education	Below high school = 1 Bachelor = 2 Master degree or above = 3
	Income level (thousand/year)	(0, 50] = 1 (50, 120] = 2 (120, 200] = 3 above 200 = 4
Travel demand	Daily transportation cost (Yuan/month)	(0, 50] = 1 (50, 100] = 2 (100, 150] = 3 above 150 = 4
	Travel distance for FFBS (Km)	(0, 2] = 1 (2, 4] = 2 (4, 6] = 3 (6, 8] = 4 above 8 = 5
	Time period of travel for FFBS	(00:00, 6:00] = 1 (6:00, 8:00] = 2 (8:00, 11:00] = 3 (11:00, 13:00] = 4 (13:00, 17:00] = 5 (17:00, 19:00] = 6 (19:00, 00:00] = 7
	Using time for FFBS (Minute/time)	(0, 5] = 1 (5, 10] = 2 (10, 20] = 3 (20, 30] = 4 above 30 = 5
	Travel purpose for FFBS	Commute = 1 Attend school = 2 Business = 3 Transfer = 4 Shopping = 5 Sports = 6
	Frequency of free-floating bicycles use (time/day)	1 = 1 2 = 2 3 = 3 4 or above = 4
Attitudes towards FFBS	FFBS makes the travel convenient	Agree = 1 Neutral = 2 Disagree = 3
	FFBS helps save time	Agree = 1 Neutral = 2 Disagree = 3
	Free-floating bicycle is locked in private lock	Agree = 1 Neutral = 2 Disagree = 3
	FFBS fare is cheap	Agree = 1 Neutral = 2 Disagree = 3
	Free-floating bicycles are convenient to park	Agree = 1 Neutral = 2 Disagree = 3
	FFBS may disclose personal information	Agree = 1 Neutral = 2 Disagree = 3
	FFBS is convenient to pay	Agree = 1 Neutral = 2 Disagree = 3
	FFBS helps for sports	Agree = 1 Neutral = 2 Disagree = 3
	Malfunction free-floating bicycles are not handled promptly	Agree = 1 Neutral = 2 Disagree = 3
	Free-floating bicycles are hard to find	Agree = 1 Neutral = 2 Disagree = 3
	FFBS policy needs improving	Agree = 1 Neutral = 2 Disagree = 3

6.3. Model Results

In order to further explore the reasons for FFBS use among urban residents, the utility function of the binary logit model is often calibrated by a maximum likelihood estimation. The estimate of the predicted parameters is obtained by seeking the maximum likelihood estimation function of the logarithm. The bivariate analysis of the independent variables is completed by SPSS, with an introductory probability of 0.05 and a rejection probability of 0.1. Independent variables and results of significance tests are listed in Table 3.

Table 3. Estimation results of the model.

	B	S.E.	Wald	df	Sig	Exp(B)
Constant	3.454	0.130	711.207	1	0.000	
Level of education (X_1)	0.168	0.018	89.608	1	0.000	1.183
Income level(X_2)	0.166	0.023	50.752	1	0.000	1.181
Transportation cost (X_3)	0.129	0.017	55.633	1	0.000	1.138
Make travel convenient (X_4)	0.134	0.026	26.300	1	0.000	1.143
Parking advantage (X_5)	0.093	0.026	12.248	1	0.000	1.097
Sports (X_6)	0.065	0.024	7.514	1	0.006	1.067
Bicycle malfunctions are not handled promptly (X_7)	−0.204	0.024	73.975	1	0.000	0.815
Limited regulations (X_8)	−0.143	0.026	29.579	1	0.000	0.867
Model checking correlation coefficient						
Nagelkerke 0.819	Cox and Snell	0.46	McFadden	0.745	Chi-square	89

According to the statistical theory, based on a confidence of 95%, if the value of significance is less than 0.05, this indicates that the variable has a significant effect on the selection result and should be retained. After selecting variables according to SPSS, eight variables that affect FFBS use were screened out. In addition to testing each feature variable by sig. separately, Chi-square, McFadden, Nagelkerke R Square, Cox, and, Snell and other parameters are selected to test the model. According to the statistical theory, the McFadden coefficient is 0.745 (more than 0.2), and the Nagelkerke R Square and the Cox and Snell are larger, it proves that the model fitting is well. Besides this, the Chi-square is 89 and the significance is less than 0.05, which shows that, under a confidence of 95%, the selected variables have a significant impact on the use of FFBS.

According to the calculation of the binary model, the probability of the user selecting an FFBS for travel is as follows:

$$P(Y=1) = \frac{P_{2n}}{1+e^{-(3.454+0.168\mathrm{X}_1+0.166\mathrm{X}_2+\ldots-0.204\mathrm{X}_7-0.143\mathrm{X}_8)}}$$

The level of education is positively related to riding FFBS and the odds for this are 1.183. That is, with the other influencing factors unchanged, the probability of using free-floating bicycles will be 1.183 of the original when the level of education increases by one unit. Maybe this is because a user with a higher educational level is more likely to accept new technological innovations. The income level is positive for the use of FFBS, and the odds for this are 1.181. This shows that each time the level of income is improved, the possibility of using shared bikes will increase 1.181 times. This is mainly because FFBS tickets are relatively expensive for low-income groups, and people with high incomes are more willing to pay for the use of shared bikes. The monthly public transportation cost is estimated at 0.129 and the odds ratio is 1.138. This suggests that with the level of monthly public transit cost being improved, the possibility of using FFBS will increase 1.138 times. This is mainly because the more travel costs, the greater the demand for short distance travel. As a result, the willingness to use FFBS increases. The parameter estimation of making travel convenient and parking advantages are 0.134 and 0.093, and the odds are 1.143 and 1.093. This shows that the more convenient the travel and the parking are, the higher the probability of using FFBS. This may be because shared bikes not only have door to door service, but also can be rented and parked at any time. This is very helpful for residents to travel. The sports parameter is estimated at 0.065 and the odds are 1.067. This shows that with the level of sports being improved, the willingness to use shared bikes increases 1.067 times. This is mainly because FFBS is not only a form of green travel, but also a type of exercise and is conducive to healthy travel.

The parameter estimation of bike malfunctions not being handled promptly is −0.204, and the odds are 0.815. This shows that as untimely handling of malfunctions increases one level, the possibility of using FFBS will increase 0.815 times. This is mainly because bike malfunctions will reduce user satisfaction and the loyalty to FFBS, reducing the use of shared bikes. Limited regulations are estimated to be −0.143, and the odds are 0.867. This suggests that the worse FFBS management policy is, the lower people's willingness will be to use FFBS. This is mainly because flawed management policies lead to FFBS operation and management confusion, resulting in poor user satisfaction, reducing the willingness to use FFBS.

The results also further proved that FFBS has become a generally accepted travel mode by residents; it has especially been accepted by the user to solve 'the first and last mile problem', and it has become a major tool for commuting and schooling. However, this new form of bike sharing has also caused a variety of problems because of its rapid development. For example, the timeliness of maintenance and the lag of related policies will inhibit the use of FFBS. Only by constantly finding and solving problems and improving policies and regulations can we meet the travel demands of users so as to make FFBS undergo active and healthy development.

It is unexpected that FFBS use was not significantly influenced by whether these bikes are difficult to find, whether it is convenient to pay and whether shared bikes are locked by private locks which could considerably limit the use of a traditional public bike. This is possibly because FFBS allows users to park their bike wherever they want; when combined with a large number of shared bikes delivered by various operators, frequent users do not consider it difficult to find available bikes. It implies that FFBS users may rarely experience that they cannot find available bikes because these are locked by other's private locks. Also, this reveals that FFBS operators have delivered a sufficient number of bikes for users since they do not perceive a lack of bikes as a problem. As for the variable convenient payment for FFBS, this may be because, with the growing popularity of mobile Internet, it is easy for residents to accept this method of payment, as a mobile application is used to pay the bicycle fee rather than IC cards. To a certain extent, this suggests the feasibility and acceptability of mobile phone payment for FFBS fees.

7. Conclusions and Discussion

In this paper, we investigate the travel behavior of FFBS users and the influencing factors of FFBS use. A detailed survey is distributed to residents in six major cities in Jiangsu province to explore their travel behavior, FFBS use, and their attitudes towards shared bikes. At first, the basic characteristics of FFBS use are analyzed, and then a binary logit model is applied to explore the influencing factors of FFBS use. The results show that shared bikes are mainly used for urban commuting and attending school in urban rush-hour. Since most of the users use FFBS for short-distance travel, this implies that FFBS has become one of the effective solutions for the "first and last mile" problem.

Most FFBS travel occurs in the city center, where workplaces, public services and recreational sites are concentrated. Since FFBS is a dockless system, users are not constrained by facilities. This therefore reflects a high demand for short-distance travel and how FFBS meets this demand. Indubitably, this demand is highly related to typical Chinese urban planning modes—a geographic concentration of high-level public services, educational resources, and health care, and employment. Thus, residents in lower-density cities may not have such a high demand for this service. To some extent, this explains why the FFBS system swiftly spread over China but is not so successful in Europe.

Moreover, income level and educational level have a significant influence on FFBS use. The higher the income level and educational level, the more willing the residents are to use FFBS. Economic considerations, convenience, parking, and health considerations have a positive impact on FFBS's use, while delayed malfunction handling and a lack of policies negatively influence people's willingness to use FFBS.

As the paper attempts to study the use of FFBS, it contributes an overview of the development of FFBS systems at the early stage, the identification of the main characteristics of FFBS use, and early adopters' attitudes towards FFBS to the literature. Nonetheless, there are limitations to the research. First, most of the respondents are younger people who have experienced shared bikes; the results may over-represent their attitude towards FFBS. In other words, other population groups, especially elderly people whose everyday life may be directly influenced by unregulated FFBS use, are unintentionally neglected in this research. It may not be a problem that previous studies mainly focus on users and potential users of shared bikes because traditional bike sharing schemes have a very limited negative impact on non-users. However, those who do not use the FFBS, or even FFBS users themselves, are suffering from the disorder it brings. Therefore, non-users' attitudes towards FFBS should also be investigated in the future. In addition, a comparison between different population groups could be interesting. Moreover, external factors, such as the traffic environment and weather changes, may have an impact on FFBS use. Therefore, in future research, more variables should be considered as influencing factors of FFBS's use. Since policy regulating FFBS's use has not yet been made, there is a pressing need to make effective policies balancing the convenience of FFBS and keeping city centers tidy.

In the context of vigorously promoting public–private partnership models in China, FFBS has become an important supplement to the urban transportation system, and it can also be supported by the government in terms of parking and delivery quantity. The research institutes can also use the mobile travel data of the non-pile type bike to analyze the actual demand for the bike in order to adjust the quantity and place of delivery scientifically and effectively. At the same time, through cooperation, we can further realize commercial management and improve the public resource utilization efficiency, as well as providing the basis for urban transportation planning.

The government should formulate corresponding management policies to guide the development of FFBS. The parking area and total number of shared bikes should be clearly defined. Those who break bikes should be punished more severely, and their misconduct behaviors should be incorporated into personal credit records. For enterprises, on the one hand, they should set up a credit system to encourage users to regulate riding and report irregularities, better credit users should be given preferential fares, and user loyalty should be improved. On the other hand, technical means to solve the problem of user parking should be developed. For example, the specific location of user parking from GPS data could be used to determine whether parking facilities are used and to handle faulty bikes in a timely manner. Finally, management measures, publicity and guidance should be improved to promote public norms regarding parking to make FFBS a common mode of transport for short trips.

There are some limitations of this study. Firstly, more advanced models have been used in the transport domain, such as the multinomial logit model, ordered logit model and structural equation modeling. However, these models are not suitable to analyze the empirical data collected in our research. Since the questionnaire does not include questions about users' general satisfaction/attitude/user experience, whether the respondent has used FFBS or not was taken as the dependent variable. We are aware that this is a weakness in the questionnaire design. Secondly, although there is little difference between cities within a province, it might be interesting to look at the differences across provinces as the strategies for FFBS development may vary across different provinces.

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