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Understanding Users' Perceptions of Bicycle-Sharing Systems in Chinese Cities: Evidence from Beijing and Guangzhou

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Abstract: Decades ago, bicycles used to play an important role in urban transportation in Chinese cities, but they have been gradually replaced by private cars, metro, buses, and some other modes, owning to the fast-growing mobility demand as a result of urban expansion and motorization. However, in recent years, with the development of Information and Communication Technologies (ICT) and the initiative of the sharing economy, bike-sharing systems (BSSs) have been implemented extensively in Chinese cities. Their usage patterns can be revealed via system-generated data, yet less is known about users' attitudes towards and preferences for these systems. In this study, we draw on two surveys conducted in Guangzhou and Beijing on the perceptions of travelers using BSSs to estimate the effect of demographic factors, bicycle ownership, and trip-level factors on the willingness and potential frequency of BSS usage. In addition, a latent class model is built to analyze the different aspects of theses systems concerned with different types of urban travelers. It is found that respondents' age, occupation, income, mode combination, and the proximity of origin or destination to the docking station, etc., influence the willingness and frequency of using BSSs. In addition, respondents generally value features such as the proximity of docking stations to trip destinations, safety to ride, and appropriate level of fare. However, different latent classes show a different preference for other features of BSSs. According to the model results, proposals are given for the improvement of the existing systems in Chinese cities.

Keywords: bike-sharing system; stated preference analysis; multinomial logit; latent class analysis

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1. Introduction

The urban transportation landscape has undergone a significant transformation in recent decades due to the widespread adoption of sharing economy platforms. These platforms, which encompass various services such as ride hailing, bicycle sharing, and auto rental, have revolutionized the way people access and utilize transportation options in urban areas. This shift has resulted in a global trend towards mobility-on-demand, where individuals can easily access transportation services as needed. In developing countries like China, which are currently facing rapid growth in motorization and urban mobility demand, the development of shared mobility is critical for the sustainability of urban transportation. Non-motorized, short-distance travel among urban residents in Chinese cities remains substantial [1]. Consequently, this has resulted in the proliferation and widespread adoption of diverse bicycle-sharing programs, including both government-led public bicycle programs and privately operated dockless bicycle-sharing systems (BSSs) [2].

The expansion of bike-sharing systems is far beyond the expectations of transportation and urban planners, particularly after the advent of dockless bike-sharing systems in 2015 [3]. According to Meddin and DeMaio (2015), China had more than double the number of BSSs than Italy by 2015 [4]. According to Zhu (2022), the total number of dockless bicycles in China had surpassed 4 million as of 2016, and Shanghai alone had an estimated 450,000 dockless shared bicycles [1].

While there are numerous purported advantages of BSSs, such as alleviating congestion, reducing emissions, enhancing the efficiency of public transportation systems, and promoting street life, several studies have presented conflicting results. In addition, BSSs today are still facing many challenges, including maintaining the just-in-time availability of bikes during peak demand, bicycle vandalism and theft, and the aberrant parking behavior of dockless shared bicycles, as well as future demand, safety, the business model, cost, and user convenience [5]. Most existing research focuses on the usage pattern of BSSs using system-generated data [2,6,7], and their corresponding effects on congestion mitigation [8,9], complementing the transit system [10], or emission reduction [1]. Less research has been conducted investigating BSSs from the point of view of user attitudes, experiences, and preferences, which is also critical for the successful implementation of BSSs [11,12]. The variance in user demographics and preferences in different cities might challenge the growth of BSSs, which have become increasingly similar and less localized across the world.

How different are users' perceptions of BSSs in different cities of China? Do the service providers of BSSs need to be concerned with the localization of their services? This paper draws on two surveys conducted in Guangzhou and Beijing by the Institute for Transportation & Development Policy (ITDP)—China in 2009 to investigate urban travelers' perceptions of and attitudes towards BSSs. This study identifies the factors influencing the likelihood and frequency of travelers using BSSs, analyzes the correspondence between users' attributes and state requirements for BSSs, and discusses how these systems could be improved to attract different kinds of urban travelers in Chinese cities. Although the surveys were majorly targeted at public bicycle systems, the information gathered could shed important light on all types of BSSs, including dockless bicycle-sharing systems.

The study contributes to the BSS literature by addressing these three issues.

(1) Developing choice models to assess the likelihood and frequency of using BSSs, as perceived by the survey respondents, and analyzing the correlations with their demographic profiles and private bicycle ownership.
(2) Using a latent class model to classify the respondents based on their opinions on different aspects of BSSs, and shedding light on how to develop and improve BSSs for different types of users.
(3) The extant body of research on BSSs is predominantly concentrated on systems implemented within Western nations, specifically North America, Europe, and Australia. Research on BSSs within the Chinese setting remains limited. Studies examining and comparing BSSs in different Chinese cities are scarce. This study offers a new perspective on bike-sharing systems (BSSs) in high-density, quickly growing Chinese cities, specifically Beijing and Guangzhou, by examining the responses and attitudes of potential riders.

The present paper is structured in the following manner: Section 1 provides an introduction to the study context and Section 2 offers an evaluation of the related literature on bike-sharing systems (BSSs), with a particular focus on the expressed preferences of users. Section 3 introduces the survey data from Guangzhou and Beijing, and gives an exploratory statistical analysis for the specific questions considered important. Section 4 employs multinomial logit models to understand the factors influencing the likelihood and frequency of using BSSs. Section 5 uses latent class models to classify the respondents into subgroups based on their attitudes toward different aspects of the systems, in order to find what aspects of the system design could be particularly addressed to meet specific population groups' needs. The last section discusses the findings and provides proposals for the development of BSSs in China.

2. Related Literature

This section examines two groups of research that are closely related to the study: the impacts of BSSs on urban transportation, and users' attitudes and preferences toward BSSs.

2.1. Impacts of BSSs on Urban Transportation

Shaheen et al. (2010, 2013) [5,13] summarized the benefits of bike sharing as six major points: the provision of flexible mobility and saving of travel time, emission and air pollution reduction [1,14], individual financial saving, reduced congestion and fuel use [8,9], and health benefits, as well as connection with public transport to solve the "last mile" problem [9,15].

Several studies have demonstrated that the implementation of bike-sharing programs has the potential to decrease both car usage and traffic congestion [8,16,17]. Wang and Zhou (2017) conducted a study examining the impact of bicycle sharing on congestion alleviation in various cities across the United States [18]. Their analysis, encompassing a total of 96 cities, revealed that the influence of bicycle sharing on congestion mitigation was more pronounced in larger cities compared to smaller ones. Huang and Xu (2023) found that the emergence of dockless BSSs resulted in a reduction in the congestion delay index by 2.2% on average in Chinese cities, and this effect was more significant on weekdays than on weekends [9].

However, other research [13,19–22] contends that the substitutive effect brought on by BSSs mostly affects non-motorized trips, and those trips using public transportation, ride-hailing services, and taxis. According to Tang et al. (2010), roughly 80% of BSS users would have chosen walking, public transportation, or private bikes if BSSs were not implemented in Chinese cities, and they concluded that anticipating the obvious impact of BSSs on reducing car use would be too optimistic [23]. Bike-sharing services also have a complementary impact on other means of transportation, in particular public transportation. The close integration of BSSs and transit systems has been found to increase patronage for both systems [23,24]. Huang and Xu (2023) also argued that dockless BSSs increase the probability of urban residents commuting by public transit based on micro-survey data [9]. However, Zhu (2022) found that the large-scale deployment of dockless BSSs in Shanghai in 2015 did not stimulate the usage of the metro system [1].

2.2. User Preferences and Demographics

Understanding the motivations and preferences of users for BSSs is important, not only for system operators, but also for policymakers and planners. However, research on this topic has not yet drawn sufficient attention [12].

Fishman et al. (2014) summarized and sorted the main motivators for users of two BSSs in Australia: Melbourne Bike Share and City Cycle. They found that convenience was the most important factor, with the proximity from the docking station to the workplace and health benefits being ranked second and third [25]. Similarly, Bachand-Marleau et al. (2012) studied the factors influencing the likelihood and frequency of using BIXI, a bike-sharing system, in Montreal, Canada [26]. They found that the proximity of the docking stations to homes was the most important factor promoting the likelihood of using the system. The presence of a docking station within 500 m of the home would increase the likelihood of an individual using the system by more than 300%. They also found that users with a yearly membership would use the system more frequently. However, Buck et al. (2013) found that 21% of female members and 13% of male members of CaBi (the BSS in Washington, D.C.) reported no riding in a typical month [27]. In a study on BSSs in Australia, Fishman et al. (2014) found a similar case, indicating that 46% of annual members reported no ride in the previous month, and only 14% of them used the system every day [25]. They assumed that many members may take bike sharing as an occasional adjunct for unexpected needs. The approach of social practice has also been adopted to understand the usage of sharing micromobility from the perspective of a bigger social and cultural configuration, by decomposing the practices into three basic types of elements:

materials (or tangible objects), competencies (or skills and knowledge), and meanings (or shared interpretations and symbolic significance) [28,29].

The demographics of bike-sharing users are of interest to researchers. Several studies have found that users of BSSs are more likely to have higher average incomes [25,27] and higher education levels [13,25]. Goodman and Cheshire (2014) found that BSS users in London were mostly from richer areas of the city, especially after the increase in fares in 2013 [30]. As for gender, several studies have confirmed that men are more likely to use these systems [13,30]. In addition, dockless bike-sharing also leads to the elderly being more disadvantaged in mobility, because this group generally has difficulty operating the system with a smartphone [12].

3. Research Context and Dataset

In this study, we compare residents' perceptions of the BSSs in Beijing and Guangzhou based on two surveys conducted in 2009. We selected Beijing and Guangzhou as our case cities for the analysis because they are both first-tier cities of China with early adoption of public BSSs and dockless BSSs, but with dramatic differences in the characteristics of their built environment, such as the size of street blocks and particularly weather. These factors could result in different preferences for and perceptions of bicycle riding. In the year 2009, the gross domestic product (GDP) of Beijing amounted to 1215.3 billion RMB, which is approximately equivalent to 160.05 billion USD (using the CNY-USD exchange rate (1 CNY = 0.1317 USD) on 31 December 2009). This economic output was accompanied by a residential population of 17.55 million. In contrast, Guangzhou had a residential population of 10.33 million with a density of 1390 persons per km^2 in 2009. The GDP of Guangzhou in 2009 was 913.82 billion RMB, or around 120.35 billion USD. The rainfall was 480.5 mm for Beijing and 1549.1 mm for Guangzhou.

In 2009, Beijing had just hosted the Olympic Games of 2008, and Guangzhou was preparing for The 16th Asian Games that would take place in 2010. Therefore, both cities had constructed or were upgrading their transportation infrastructure city-wide. In addition, both cities were under a rapid process of motorization at the time that the surveys were conducted. Vehicle ownership had reached 220 cars per 1000 persons in Beijing and 189.2 cars per 1000 persons in Guangzhou. Congestion and emissions had become growing concerns for local governments. Government-led bicycle-sharing programs became an option for the promotion of green transportation and were seriously considered and treated in both cities.

Public bicycle-sharing systems emerged in Guangzhou in June 2010 and landed in Beijing in 2012. Before the arrival of public BSSs in the two cities, there were already some companies providing bicycle-sharing services. For example, Bike Blueprint managed a fleet of over 8000 shared bicycles in around 100 stations in Beijing in 2008, when its size reached its peak. Figure 1 shows the change in the mode splits of the two cities in 2005 and 2017, respectively. The share of bicycles experienced a significant decrease in Beijing from 2005 to 2017, but an evident growth in Guangzhou over the same period. However, it is noteworthy the statistics of bicycles in Guangzhou in 2017 also include the count of electric bicycles.

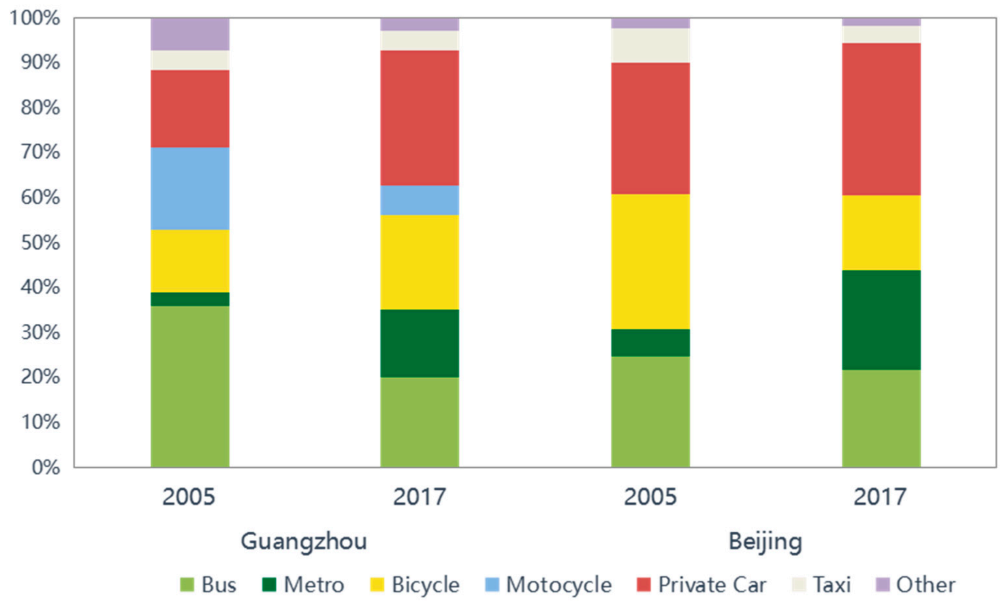

Figure 1. The mode split of Beijing and Guangzhou in 2005 and 2017 (after excluding the share of walking).

The data in this section were acquired from the Institute for Transportation and Development Policy (ITDP), China, based on surveys conducted in Guangzhou and Beijing in 2009. ITDP is a global organization working with the local governments of cities across the world to promote sustainable transportation and urban development in order to mitigate the impacts of climate change, improve air quality, and support prosperous, sustainable, and equitable cities. The purpose of the ITDP surveys was to "gather accurate and reliable data on the demand, aspects, attributes, needs, profile, and overall necessities of cyclists with a preference for bicycle parking, rental, and sharing facilities". The survey locations were pre-identified, including residential areas, bicycle parking lots, and transit stations, especially those along the BRT and Metro lines, as BSSs are usually considered to be a first-mile/last-mile connection option for public transportation. The surveys were conducted on weekdays in the morning and afternoon, with short interviews of residents in selected communities, passengers of public transportation at stations, and bicycle riders at parking facilities using a standardized questionnaire.

The survey in Guangzhou covered questions ranging from the respondents' demographic information, such as age, gender, occupation, income category, bicycle ownership, trip information, and attitudinal questions, including the willingness for and frequency of using shared bicycles, to the aspects or features of the bike-sharing systems that they thought were important. The questionnaire in Beijing was similar to that of Guangzhou, but added some more specific questions about the usage experience of the bike-sharing system, such as how the respondents managed the part of trips made using bike sharing before the start of the service, the locations that the respondents hoped to have more docking stations, and their means of payment when using the rental service. It is noteworthy that, at the time of the survey, a public bicycle-sharing system had been launched in Beijing, but none existed at a comparable scale in Guangzhou.

A total of 1342 effective questionnaires were reclaimed in Guangzhou. In Beijing, the number of effective reclaimed samples was 278, because many questionnaire answers were incomplete. Table 1 lists the composition of the respondents by age group, gender, and occupation.

Table 1. Statistics of survey respondents.

City	Number of Respondents	Age Group					Gender	
		≤18	19–30	31–44	45–60	>60	Male	Female
Guangzhou	1342	8%	63%	21%	7%	1%	51%	49%
Beijing	278	5%	58%	26%	9%	2%	53%	47%
City	**Occupation**							
	Student	Public sector	Commercial and service	Company	Housewife	Freelancer	Migrant workers	Other
Guangzhou	14%	5%	14%	17%	12%	14%	13%	11%
Beijing	25%	14%	10%	32%	5%	4%	2%	8%

Mode Substitution

The survey in Beijing asked the respondents how they managed the part of the trip made using bike sharing before the BSS service started, intending to find out which modes were replaced by BSSs. According to Figure 2, it appeared that over half of the respondents used their own bicycles for the trips later made by BSSs. The remaining respondents mostly reported walking or using public transportation. Only around 5% of the respondents were shifted from using a taxi or private car. The findings of the survey align with the results drawn from previous research conducted on BSSs in China [31], as well as in other countries [30]. One of the primary aims of bike-sharing initiatives is to mitigate the number of car journeys undertaken in urban transportation, hence resulting in decreased fuel consumption, air pollution, and lessened congestion within the city. The survey results have prompted an inquiry into the potential impact of bike sharing on reducing automobile usage, and the extent to which it may do so.

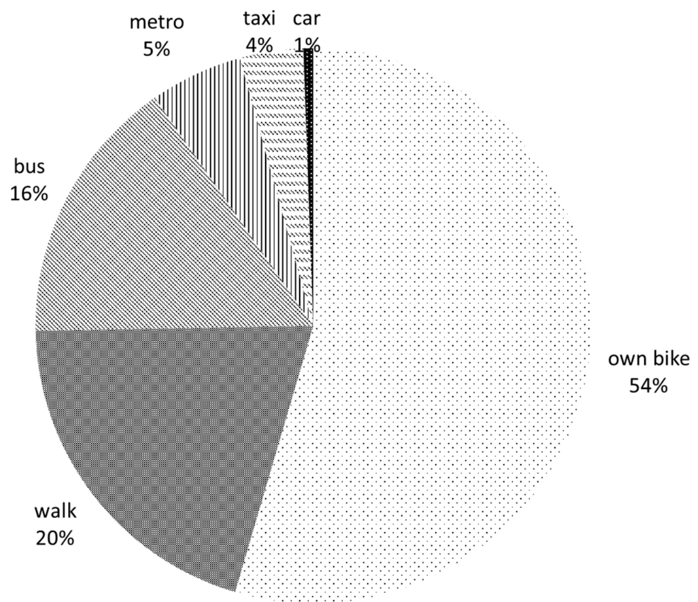

Figure 2. Traffic modes were replaced by bike sharing in Beijing.

4. The Likelihood and Frequency of Using BSSs

In this section, choice models are built based on the survey data to assess the perceived likelihood and frequency of using BSSs in Guangzhou and Beijing.

4.1. Likelihood of Using BSS

Unlike Beijing, Guangzhou's survey was conducted before the BSSs program was implemented. Therefore, in the Guangzhou survey, the respondents were asked, 'Are you willing to use a bike-sharing system if the service is launched?' The questionnaires were distributed at 72 locations, which could be classified into three major types: residential neighborhoods, bicycle parking facilities, and transit stations. Binary logistic regression was employed to estimate the factors that influenced the respondents' willingness to use bicycle-sharing systems in Guangzhou. The result of the model is listed in Table 2.

Table 2. Factors influencing the likelihood of using bike sharing.

Variables	Coefficients	*t*-Test	Signif.
Age under 18	0.514	0.033	**
Age between 31 and 44	−0.255	0.115	
Own a bike themselves	−0.521	0.001	***
Ride their own bike 1–3 times a week	0.408	0.102	
The self-owned bike costs less than 100 RMB	−0.523	0.111	
The self-owned bike costs 500–1000 RMB	0.428	0.184	
Like riding city bikes	−0.238	0.132	
Like riding racing bikes	0.704	0.001	***
Like riding old-style bikes	−0.805	0.001	***
Work as a government officer	−0.739	0.027	**
Work in a company	−0.656	0.001	***
Migrant workers from other cities	−0.816	0.000	***
Monthly income is 2000–4000 RMB	0.499	0.008	***
An answer sheet is not complete	−0.314	0.068	*
Log-Likelihood: −776, McFadden R^2: 0.14597			
Likelihood ratio test: chisq = 265.26 (p.value $\leq 2.22 \times 10^{-16}$)			

Significance note: * $p < 0.1$; ** $p < 0.05$; and *** $p < 0.01$.

The model results indicated that respondents aged below 18 and between 19 and 30 showed a greater willingness to use bike sharing. For students and youth, BSSs provide a convenient and inexpensive way of urban travel. The respondents who owned bicycles themselves were less likely to use bike-sharing services. However, the respondents who had rented bicycles before showed a significant propensity for using BSSs. This indicates the potential of BSSs to attract travelers who used to ride their own bicycles for daily trips if the system could make them try it for the first time. In contrast to other income groups, the low–medium income group was more likely to use BSSs. Low-income groups may avoid spending on bike-sharing services.

The model results also showed that retail workers and housewives were more likely to use BSSs than other groups, such as company or public sector employees. Those with typical daily trips with first-mile/last-mile connection distance of around 5–10 min of walking had a greater propensity for using BSSs. However, when the connection distance was over 20 min of walking, the likelihood of using BSSs was significantly reduced. This suggests that bike-sharing is only appropriate for short-distance trips for most travelers. Finally, it is noteworthy that the respondents surveyed in residential neighborhoods or bicycle parking facilities showed negative attitudes toward using BSSs in comparison to the respondents sampled at transit stations. This shows that BSSs were more acceptable as connection modes for public transit systems.

4.2. Frequency of Using System

In both surveys, the respondents were asked to choose among the options ("never or seldom", "once a week", "several times a week", and "every day") that best answered the question "How often will you use a bike sharing system if the service exists?". In this study, two multinomial logit models are calibrated to assess the respondents' attitudes toward the potential frequency of using BSSs weekly. The results are reported in Table 3, and the base alternative option is "never or seldom".

Table 3. Factors influencing the frequency of using BSS.

	Guangzhou			Beijing		
Variables	**Coef.**	***p*-Value**		**Coef.**	***p*-Value**	
Demographic and economic characteristics						
Female (several times a week)	−2.215	0.024	**			
Age between 24 and 30 (several times a week)				−1.353	0.118	
Age between 24 and 31 (everyday)				1.526	0.074	*
Age between 31 and 44 (everyday)	−1.760	0.154				
Student (once a week)				2.363	0.028	**
Student (several times a week)	1.955	0.128		3.832	0.001	***
Student (every day)				−2.411	0.025	**
Commercial service staff (several times a week)	3.884	0.006	***			
Work in a company (several times a week)	2.694	0.058	*			
Freelancer (several times a week)	3.188	0.018	**			
Monthly income is less than 2000 RMB (several times a week)	−1.616	0.051	*			
Monthly income is less than 2000 RMB (every day)	−0.939	0.120				
Bicycle ownership and preference						
Own a bike themselves (once a week)	−1.230	0.081	*			
Own a bike themselves (several times a week)	−2.579	0.004	***			
Self-owned bike costs 500–1000 RMB (once a week)	1.632	0.108		1.556	0.123	
Like riding folding bikes (every day)	2.124	0.035	**			
Like riding city bikes (several times a week)	3.332	0.019	**			
Like riding city bikes (every day)	1.562	0.134				
Like riding racing bikes (every day)	2.626	0.016	**			
Like riding old-style bikes (several times a week)	3.200	0.031	**	−3.281	0.026	**
Like riding old-style bikes (every day)	2.034	0.068	*	−2.107	0.110	
Seldom ride own bike (once a week)				−3.582	0.001	***
Seldom ride own bike (several times a week)				−4.596	0.001	***
Seldom ride own bike (every day)				−5.679	0.001	***
Walking from docking station to destination (>20 min)						
5–10 min walk from docking station to destination (every day)	2.651	0.042	**	2.774	0.023	**
5–10 min walk from docking station to destination (once a week)				2.927	0.018	**
5–10 min walk from docking station to destination (several times a week)				2.811	0.024	**
10–15 min walk from docking station to destination (once a week)				3.020	0.005	***
10–15 min walk from docking station to destination (several times a week)				3.453	0.001	***
10–15 min walk from docking station to destination (every day)				2.340	0.029	**
15–20 min walk from docking station to destination (several times a week)	−2.073	0.085	*			
Other factors						
Pay each time (once a week)				−1.825	0.049	**
Pay each time (several times a week)				−2.290	0.015	**
Pay each time (every day)				−3.075	0.001	***
Drinks are sold at the docking station (once a week)				2.706	0.004	***
Drinks are sold at the docking station (several times a week)				2.171	0.018	**
Drinks are sold at the docking station (every day)				1.938	0.030	**
Repair service provided at the docking station (once a week)				3.481	0.007	***
Repair service provided at the docking station (several times a week)				3.449	0.008	***
Repair service provided at the docking station (every day)				2.198	0.099	*
Log-Likelihood	−197.72			−216.53		
McFadden R^2:	0.36269			0.42563		

Significance note: * $p < 0.1$; ** $p < 0.05$; and *** $p < 0.01$.

As the model results indicated, in Guangzhou, the respondents between 31 and 44 years old were less likely to use bike sharing frequently, as were female respondents. In Beijing, the respondents between the ages of 24 and 30 tended to use the systems less frequently. There was no significant relationship between the respondents' gender and bike-sharing frequency in Beijing. In terms of the impacts of bicycle ownership, the respondents in Guangzhou who had their own bikes tended to use bike sharing either with a relatively low frequency or very high frequency. Some of them may have used bike sharing to replace their own bikes, but some would keep using their own bikes. The same trend was found in Beijing. Those who seldom rode their own bikes would seldom use bike sharing too. It was also found that the respondents whose favorite bikes were folding bikes, city bikes, racing bikes, and old-style bikes would consider using bike sharing more frequently in Guangzhou. However, the respondents who liked riding old-style bikes in Beijing would use the system less frequently, the opposite case to Guangzhou, but this seems to be a more rational trend. Students were found to be frequent users in both Guangzhou and Beijing. However, the model results in Beijing indicated that students tended to not use bike sharing every day. The respondents who were freelancers, worked for commercial services, or worked in a company were more likely to be frequent users in Guangzhou. Quite the opposite case was found among the respondents who had a relatively lower income. However, there was no finding related to income and use frequency in Beijing.

The proximity of docking stations to the origin or destination was always found to be an important factor influencing bike-sharing use. In Guangzhou, it was found that a 5–10 min walk from the docking station to the destination would promote high-frequency use, but if the walking time from the docking station to the destination exceeded 15 min, the use frequency would decrease. The same case was found in Beijing. A 5–15 min walking distance from the docking station to the destination was within the scope that would encourage the respondents to use bike sharing more frequently.

5. User Perceived Important Aspects of BSS

In both surveys, the respondents were asked to choose the features of the BSSs that they considered to be important. The two surveys listed almost the same list of BSS features (Figure 2), but were designed in different ways. In Guangzhou, the respondents were prompted to select the five most important aspects of the BSS. In the Beijing survey, the respondents were asked to rate the importance of the aspects from "not important at all" to "very important" (Figure 3).

C5) How important are the following physical aspects of the rental system? Rate the importance of each one:

1 being very important and 4 not important at all

	1	2	3	4
Close to station	[ ]	[ ]	[ ]	[ ]
Secure	[ ]	[ ]	[ ]	[ ]
Modern and high-quality appearance	[ ]	[ ]	[ ]	[ ]
Friendly personnel	[ ]	[ ]	[ ]	[ ]
Covered	[ ]	[ ]	[ ]	[ ]
Visible	[ ]	[ ]	[ ]	[ ]
Video surveillance	[ ]	[ ]	[ ]	[ ]
Selling of related items	[ ]	[ ]	[ ]	[ ]
Bike repair included	[ ]	[ ]	[ ]	[ ]
Affordable	[ ]	[ ]	[ ]	[ ]
Fast and convenient	[ ]	[ ]	[ ]	[ ]
Open 24 hours	[ ]	[ ]	[ ]	[ ]
Availability of Bikes / Facilities	[ ]	[ ]	[ ]	[ ]

Figure 3. Aspects of the rental system (BSSs) for rating in the survey.

To extract the differences in the perceptions of the listed aspects of BSSs and the underlying socioeconomic characteristics of the respondents, a latent class analysis (LCA) model was employed. The respondents' perceptions of the BSS features were set as observed variables. In the case of Guangzhou, if a factor was picked, then it was considered to be "important" and labeled as 2. Otherwise, the factor was considered as "not important" and labeled as 1. In the case of Beijing, four different levels of importance were labeled from 0 to 3, representing "not important at all" to "very important". Fifteen variables representing the respondents' attributes, including their age, gender, occupation, and income category, were included as latent variables. The models were run in R programming using the package "poLCA".

5.1. Introduction of LCM

The basic form of the latent class model is a finite mixture model that assumes that component distributions are multiway cross-classification tables and that all variables are mutually independent. The latent class model approximates the joint distribution of the observed variables as the weighted sum of a finite number R of cross-classification tables. This model was originally proposed by Lazarsfeld (1950) using the term "latent structure analysis" [32].

In this study, the analysis was run by R programming using the package "poLCA". The model was run 200 times to obtain the best log-likelihood among several local best solutions. We tried the number of latent classes from two to four for both the cases of Beijing and Guangzhou. Measures of the goodness of fit, such as AIC and BIC, are reported in Table 4. It was found the number of classes of three was an appropriate option for distinguishing the characteristics of the respondents and their perceptions between latent classes.

Table 4. Goodness of fit of the latent class analysis models with 2–4 classes.

	Observations	**AIC**	**BIC**	**Maximum Log-Likelihood**
		Panel A: Guangzhou		
2 Classes	1170	17,299.83	17,522.68	−8605.91
3 Classes	1170	17,063.18	17,443.04	−8456.59
4 Classes	1170	16,989.2	17,476.07	−8363.60
		Panel B: Beijing		
2 Classes	230	3815.81	4145.04	−1840.16
3 Classes	230	3840.16	4218.35	−1810.08
4 Classes	230	4296.28	4817.78	−1995.98

5.2. Comparison and Summary of LCM Results

The respondents were divided into three latent classes for both Guangzhou and Beijing to balance the interpretability of the results and the variety among the classes. We also filtered the respondents who typically used private cars or taxis for their trips as separate groups for comparison. The results are presented in Table 5 and Figure 4.

Among all features, the proximity of docking stations, safety to ride, and fare were the three aspects of BSSs that the respondents considered to be important in both Guangzhou and Beijing. The modern design of sharing bikes and selling services at docking stations were two aspects that both the Guangzhou and Beijing respondents thought not to be very important. This is, in part, consistent with the findings of some early studies, which considered a lack of safety as a major barrier to cycling [17,27].

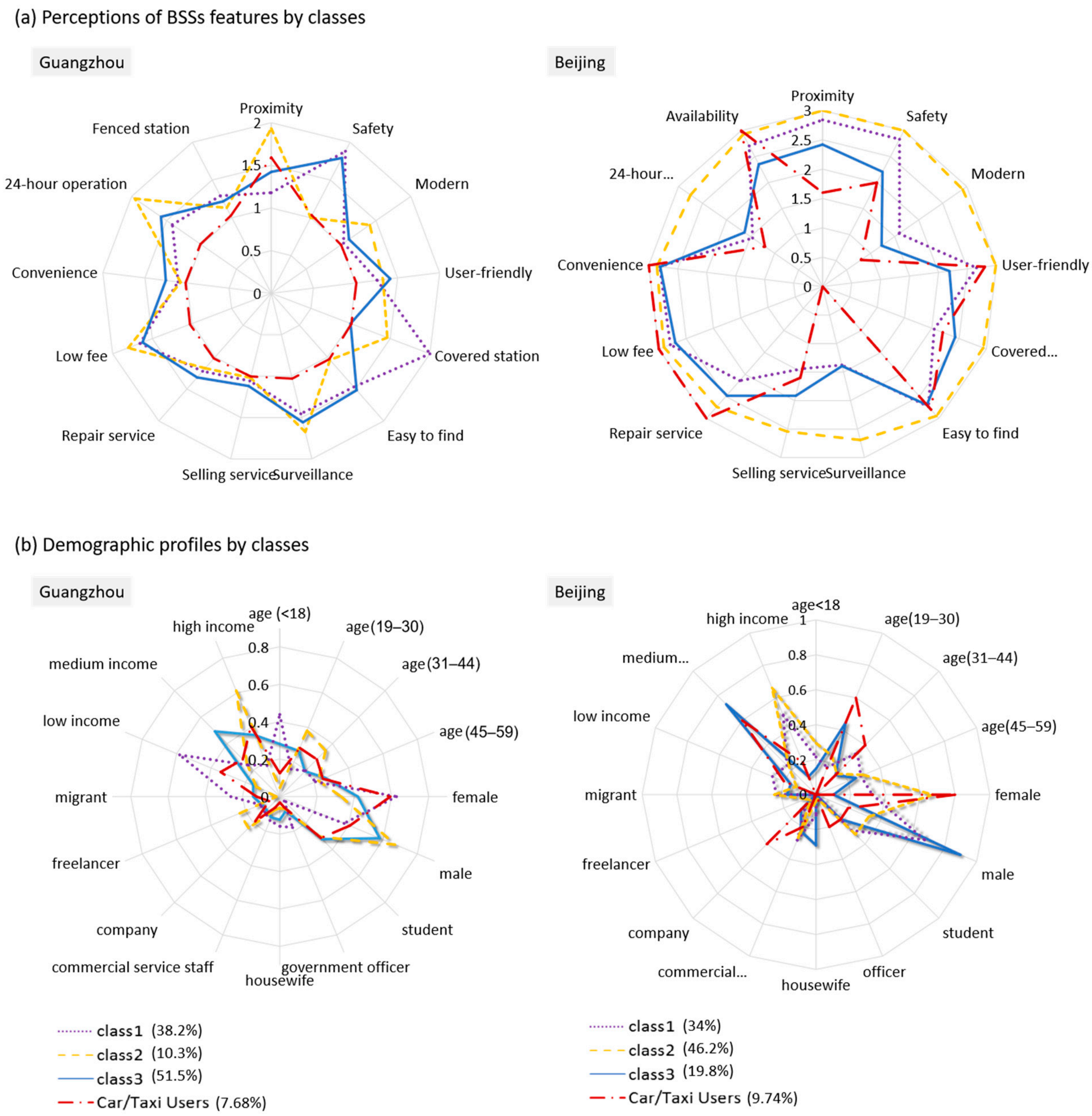

Figure 4. Perceptions of BSS features and demographic profiles by latent classes and car/taxi users.

Table 5. Summary of the latent class analysis models.

Latent Classes	Major Social–Economic Characteristics	Important Aspects	Not Important Aspects
Guangzhou (3 classes, AIC: 17,063.18, maximum log-likelihood: −8456.59)			
Class 1 (38.20%)	Age under 18, female, low income	Covered station, safe, low fare	Modern, selling service at the station, convenient
Class 2 (10.30%)	Age 19–30, age 31–44, male, student, company employee, freelance, high income	24 h, close, low fee	Safe, selling service at the station, easy to find
Class 3 (51.50%)	Male, medium income	Safe, low fee, 24 h	Covered station, modern, selling service at the station
Beijing (3 classes, AIC: 3840.157, maximum log-likelihood: −1810.078)			
Class 1 (34.00%)	Age 31–44, male, high income	Close, safe, convenient	Video surveillance, selling service at station, 24 h
Class 2 (46.20%)	Age < 18, age > 45, female, student, high income	Safe, close, friendly	Selling service at the station, video surveillance, and repairing service at the station
Class 3 (19.80%)	Age 19–30, male, medium income	Convenient, low fare, easy to find	Modern, video surveillance, 24 h

As shown in Table 5 and Figure 4, the respondents in Guangzhou and Beijing also had different views on some features of BSSs. The respondents in class 1 of Guangzhou and class 2 of Beijing shared a similar demographic profile, such as an age under 18 years and being female. As expected, both groups of respondents regarded safety as an important factor for BSSs. However, the girls in Guangzhou were more concerned about aspects such as covered stations and low fees, while those in Beijing considered almost all aspects of the system to be important, but paid special attention to the proximity of docking stations and the friendly use of BSSs. One explanation for this phenomenon may be that Guangzhou (southern China) has more precipitation than Beijing (northern China). Accordingly, it is suggested that docking stations in southern China be covered to prevent bicycles from getting wet by rain.

The male respondents aged between 31 and 44 in Guangzhou differed from their counterparts in Beijing in that they cared more about the 24 h operation of BSSs. Lifestyle is known to differ between the two cities. Citizens in Guangzhou and some southern cities tend to work longer hours in the evening, or take part in entertainment and eating out activities late at night, so more people may hope that bike-sharing systems can be operated 24 h a day. In contrast, the respondents in Beijing considered it to be the least important factor, but generally preferred stations with repair services.

In comparison with the three latent classes, the private car and taxi users in Guangzhou were more likely to be high-income and female company employees. They appeared to have a somewhat indifferent attitudes towards BSSs. The only aspect of BSSs that they thought was important was their proximity to the origins and destinations of trips. This is in line with the findings of early studies in other contexts, which suggested that males and younger populations account for the majority of docked bike-sharing users [33,34].

The private car and taxi users in Beijing tended to be medium-income female company employees aged between 19 and 30. They highly regarded many aspects of BSSs, including the availability of bicycles, ease of finding the system, user friendliness of the system, convenience, low fees, and repair services.

In summary, the preference analysis conducted on the surveys in Guangzhou and Beijing brings forward an inquiry regarding the amount to which bike-sharing helps in the reduction in automobile usage in urban areas of China. The majority of the replacement impact was observed among those who opted to utilize their personal bicycles, engage in walking, or utilize public transportation systems.

6. Discussion and Conclusions

The implementation of Bike-Sharing Systems (BSSs) in numerous cities across the world has stimulated a surge in academic attention towards investigating the societal, environmental, and economic advantages associated with BSSs. While there has been a growing penetration rate of BSSs in Chinese cities, empirical research examining the preference for BSSs from the perspective of users is scarce. This study drew on surveys on BSSs in Guangzhou and Beijing, as well as BSS trajectory data and the transit smart card transaction data of Guangzhou, to shed light on the question of whether BSSs can mitigate emissions by reducing car travel or facilitating public transit systems. First, the factors influencing travelers' willingness to use BSSs were estimated using the survey data from Guangzhou, which had not implemented any BSSs. Second, the respondents were classified into subgroups based on their perceptions of the various aspects of BSSs. The demographic profiles of these classes of respondents were analyzed in juxtaposition with the importance rating of the features of BSSs.

The analysis of the survey results raises the question of whether and to what extent bike sharing contributes to emission mitigation by reducing car travel. Approximately only 1% of the surveyed BSS users in Beijing switched from car travel. In addition, the analyses also showed that travelers in the two cities had some different attitudes towards and preferences for BSSs, despite having similarities. Gender and occupation were correlated with usage frequency in Guangzhou, but appeared not to be significantly relevant in Beijing. The respondents in Guangzhou favored BSSs with a 24 h operational service and covered and surveilled stations, while the respondents in Beijing cared more about convenience and repair services.

According to the survey results and analyses, some points could be proposed to promote bike-sharing use and improve the current BSSs in China:

- The services of BSSs need to be tailored to satisfy the varying demands of the travelers in different cities.
- Multiple ways of payment. The system should allow users to use and pay their fees in different ways. Many existing BSS systems, especially dockless systems, rely on smartphone apps to proceed and pay for their usage. However, some groups of travelers, such as low-income or elderly people, might have difficulty using these apps. Traditional ways of payment such as transit cards might be more appropriate for them.
- With the prevalence of dockless BSSs, vandalism and improper parking have also become more serious. Parking regulations need to be imposed, and necessary services such as repair and raincoat rentals could provided to attract more potential users.

This study had several limitations. First, the surveys were mainly carried out in three types of selected urban locations: transit stations, parking lots, and residential areas. The respondents might not have been able to represent all travelers in the two cities. Second, the surveys were conducted in 2009, mainly aimed at gathering travelers' attitudes toward station-based public bicycle-sharing systems.

In general, while bicycle-sharing systems (BSSs) offer evident social and economic benefits for commuters as a convenient and sustainable method of transportation, their environmental impact may not align with initial expectations due to their low substitution effect on cars, as indicated by the research conducted in two major cities in China. In addition, despite dockless BSSs providing a greater flexibility for users, they also generate some negative consequences on cities, arising from oversupply and inadequate parking regulations. It is common that improperly parked dockless shared bicycles clutter sidewalks, bike pathways, and public spaces and block the navigation of pedestrians and people with disabilities [12]. This is especially true in the blocks around metro stations and other major destinations at peak hours, which substantially reduces those areas' appeal by making them less walkable. Therefore, to comprehend the external effects of BSSs on cities and help urban policymakers to perform a more objective assessment when regulating or supporting BSSs, studies on the attitudes of BSS non-users are also warranted.

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