The study of Coopetition between Public Bus and Bike Sharing based on Environmental Protection

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Abstract. Recently, the traditional travel modes and public transportation system in urban areas have undergone some subtle changes under the impact of shared bikes, especially for public bus, which is the most impacted by the shared bikes. Therefore, this paper mainly aims at studying the impact of shared bicycles on the public bus from both competitive and cooperative perspectives. More specifically, this study will explore the coopetition relationship between these two modes from travellers’ behaviour perspective. An SP survey has been conducted on traveller in Beijing and a Multinomial Logit model was adopted to quantitatively analyse the effect of various factors on travellers’ modal choice between bus and shared bikes. In this study, the estimation results show that the travel distance, road infrastructure, and travelers’ psychological factors all suggest a competition between bus and bike sharing. On the contrary, distance between bus transfer stations will also lead to modal cooperation. Finally, some policy implications have been proposed to better facilitate public transports and promote the sustainable development of whole urban transport system.

1 Introduction

Recently, shared bikes become a new trend of urban transportation system, which are a prominent component of the sharing economy (Shaheen S A, 2016). In particular, bike-shared scheme has gain increasing attentions, which can be seen as facilitating travel to the public transportation in China. While facilitating the transfer of other traffic modes, sharing bikes also brings new impact on the traditional transportation system. To better cope with these effects, coordinate urban traffic system and maximize the overall benefits of social economy, it is meaningful to explore the relationship and interaction mechanism between shared bicycles and other public transportation system.

This paper focus on studying the interaction between shared bikes and public bus, which is under the more significant impact of sharing bike system (Elliot W. Martin, et al., 2014). Judging from the existing researches, the discussion on the relationship between shared bicycles and public bus is still limited. And among these cases, the relationship will different resulting from various influencing factors, such as built environment (Wafic El - along, et al., 2015), travel distance, travel destination and motivation (Julie Marleau Bachand, 2012), weather, personal psychological factors, etc. (Alexandros Nikitas, 2018). Few studies have combined factors to conduct empirical research, which enhances the motivation of this research. The remainder of the paper is structured as follows: Section 2 provides a brief overview of related literature and some existing case studies worldwide. Section 3 introduces the research methodology for this study. Section 4 presents estimation results of measured models and influence analysis of diverse factors on relationship between bike sharing and public bus. Further, some implications for transport policy-making are discussed in section 5, before drawing some tentative conclusion in section 6.

2 Literature review

From the existing research, there are two themes that pertain to the relationship between bike sharing and public transit: modal competition and modal cooperation. And there are a variety of factors affecting the relationship between public bus and bike sharing. Compared with abundant international studies, we have found that there are limited relevant studies in China in terms of different influencing factors on these two relationships. The most relevant ones are presented in details in the following paragraphs.

2.1 Competition modal

Shared bikes are emerging as a strong substitute of public bus in some studies. Some areas in Washington and Minneapolis (Elliot W. Martin et al., 2014), with low-density population, suggested that shared bicycles always feed public transit, while shared bicycles in densely populated areas is more convenient and efficient, competing with existing public bus systems. In New York (Kayleigh B. Campbell et al., 2017), travellers who often use shared bicycles are about 35 years old, and the
male accounted for 77%. The usage of shared bicycles in Chicago, USA is greatly affected by bicycle lane density, public transit accessibility, and public safety (Sun et al., 2017). About the cases in Copenhagen, Denmark, they certified that green environment along the road is mentioned as a factor of increasing riding distance (Vedel et al., 2017). In Stockholm, Sweden, it’s appeared that if the most frequently used bus lines appropriately increase driving frequency, there would be more bus users (Borjesson, 2018). After an green investment funded by the National budget and maintained by the City, a kind of cycling culture come into being with it in the small town (Nikitas, 2018).

Hangzhou, China (Susan A. Shaheen et al., 2011) found that those who have no cars use shared bicycles instead of public bus. The levels of travel satisfaction will be negatively affected by over-crowding on bus, road congestion and transfer between modes or deficient services in Xi’an, China, increasing the probability of choosing to share a bicycle increases (Titheridge et al., 2016).

2.2 Cooperation modal

Sharing bike is not always competing with public buses. In Paris, France (Rahul Nair et al., 2012), the close connection between public transit and bicycle-sharing system and multi-modal transport fare significantly increase the usage of bike sharing. Shared bicycles in London, UK (Saberi et al., 2018) are integrated into the public transport system and form an interdependent relationship with other public transport vehicles.

The integration of bicycles and public transportation is largely determined by government policy support in north America (Pucher et al., 2009): planning bicycle routes and docks besides bus stops can increase the possibility of connecting with bus routes. Interestingly, Mexico (Annie Chang et al., 2017) opened a rapid transit (BRT) in urban watersheds, improving street facilities and the environment, increasing the number of people riding from 30.38% to 33.96%, visible in public facilities. The researches of the Netherlands, Germany, and the United Kingdom (Martens, 2004) showed that the distance between public transport and import and export are closely related to the combination of public transportation and shared bicycles.

China’s Xi’an Economic and Technological Development Zone (Liu Yang et al., 2014) studied the influencing factors of the bike-and-ride mode usage: short distance between stations, bike-and-ride integrated service cards and so on.

3 Methodology

3.1 Model constructing

Travellers will choose different travel modes according to their personal preference, including public bus, shared bicycles, subway, private car, taxi and walking and so on. Considering the cooperation between bus and bike sharing, especially, the study addressed another cooperative option, which is bike sharing + public bus. In order to explore the effect of influencing factors on travel mode choice and relationship between public bus and bike sharing, this study adopted Multinomial Logit Model (MNL), and adopting participants’ concrete modal choice as discrete dependent variables. At the same time, there are multiple independent variables. Therefore, the estimating equation of probability of choosing travel mode i for traveller q is as follows,

\[ p_{iq} = \frac{\exp(bV_{iq})}{\sum_{j=1}^{J} \exp(bV_{jq})} = \frac{1}{1 + \sum_{j=1}^{J} \exp(b(V_{iq} - V_{jq}))} \]

where \( b \) is the constant term, \( j \) represents a selection of all travel mode options, \( V_{iq} \) represents the utility determinants affected by observable factors when the traveller q chooses travel mode i, and the equation is as follows,

\[ V_{iq} = \alpha_i + \sum \theta_{ij} x_{iq} \]

where \( \alpha_i \) is the constant. \( \theta_{ij} \) refers to coefficient of independent variables \( X_{ij} \) on dependent variables \( V_{iq} \). Finally, based on different scenarios, three multinomial logit models were established for the 7 categories of 43 independent variables.

3.2 Data collection and processing

3.2.1 Data source

The data were investigated by stated preference questionnaire survey (SP survey) in this study, and a total of 806 questionnaires were collected. 564 of them are valid (the valid rate is about 70%) and usable after screening based on travelling scenario. In order to guarantee the breadth and effectiveness of data source, both face-to-face and web-based methods were used to solicit respondents for this research. The scale is divided into 7 aspects as follows: socio-demographic characteristics, trips characteristics, built environment, natural environment, price incentives, availability of related information and also subjective variables.

3.2.2 Data measurement and processing

The socio-demographic characteristics of sampled travellers are presented in table 1. Statistically, the respondents are almost equally split between the genders. Considering the research related with travel mode choice that include bus, shared bike and other options, the target samples should be consisted of the young, who are more likely to use shared bicycles (Research, 2017). Therefore, there are more young (53.2% under 30 years old) participants in our SP experiment. And the personal
monthly income of more than 60% respondents is less than 4,000 yuan. Among all the respondents, there are 53.19% travellers have at least one household car, 52.66% travels live in a first-tier city and 17.02% travellers live with in a fourth-tier city or other smaller city (according to economic development levels and population size, cities are ranked from large to small as first-tier, second-tier and so on in China). In terms of self-reported health, more than 70% participants think they are healthy.

Table 1. The socio-demographic characteristics of sampled travellers

| Socio-demographic variables | No.  | Pct. (%) |
|-----------------------------|------|----------|
| Gender(X1)                  |      |          |
| Female                      | 315  | 55.85    |
| Male                        | 249  | 44.15    |
| Age(X2)                     |      |          |
| <=18                        | 102  | 18.09    |
| 19-30                       | 198  | 35.11    |
| 31-50                       | 222  | 39.36    |
| >50                         | 30   | 5.32     |
| Personal monthly income(X3) |      |          |
| Less than ¥1,000            | 231  | 40.96    |
| ¥1,000-¥4,000               | 142  | 25.18    |
| ¥4,000-¥8,000               | 128  | 22.70    |
| More than ¥8,000            | 63   | 11.17    |
| Household car number(X4)    |      |          |
| 0                           | 264  | 46.81    |
| 1                           | 219  | 38.83    |
| >1                          | 81   | 14.36    |
| First-tier city             | 297  | 52.66    |
| Second-tier city            | 108  | 19.15    |
| Third-tier city             | 63   | 11.17    |
| Fourth-tier city or above   | 96   | 17.02    |
| Very good                   | 177  | 31.38    |
| Good                        | 252  | 44.68    |
| Fair                        | 117  | 20.74    |
| Poor                        | 18   | 3.19     |

According to survey, the influencing factors on respondents’ travel modal choice and their structural distribution are displayed. There are 70.74% participants whose daily congestion time is less than 10 minutes but 12.77% travellers’ experiences daily congestions for more than 20 minutes, which is closely related to travellers’ mode choice, especially during peak-hours. Most respondents chose 2km as the acceptable maximum riding distance, accounting for 41.49% and 38.3% respectively. There are 37.23% travellers regarding 5km as the maximum riding distance, since there is no concrete time limit for leisure purpose.

Considering the travel convenience, distance from origin to bus station and distance between two transfer stations are important factors affecting travellers’ choice. The investigation finds that the longest distance participants can accept is between 500-1,000 meters. In addition, it’s obvious that about 90% respondents will choose bus if the bus frequency increases or the fare price is cheaper. Also, more than 65% travellers will increase bike using if there are more greenness on road or discounted price, nevertheless, more than 50% travellers will decrease bike choosing because of unreasonable bike distribution, high damage rate of shared bike and extreme weather.

Finally, from the perspective of trip, built environment, availability of information, social norms (William, 2016) and feelings of using, the respondents were investigated about their subjective willingness to choose travel modes, especially between bus and bike sharing, with response on a scale from “highly disagree” to “highly agree”.

4 Results of measure models

The results of estimation are shown in table 2, which are include all the significant variables and omit the non-significant ones. And the Pseudo R-square values for the models are greater than 0.4, which can be interpreted as a very good goodness of fit so that the models are considered to have reasonably good explanatory qualities (Munshi T, 2016). Furthermore, the variance expansion factors (VIF) of all variables for the models are less than 10 passing the Multicollinearity test (Marzucchi and Montresor, 2015).

4.1 Results analysis on competition

There are some findings as follows in the perspective of competition as shown in table 2. Firstly, household vehicles will have more significantly negative effect on bike sharing choice than public bus, which is probably because of its protective effect on travellers. And surprisingly, people in small size cities will tend to take public bus rather than bike sharing or other travel modes, where there may be limited resource of shared bike
program, subway construction project and private car. The more time of congestion on the ground, the less likelihood to choose bus. Quite unexpectedly, the travellers with poor health will be more likely to choose bike compared with other travel mode, same as the results of survey in Xi’an (Helena Titheridge et al., 2016), which may because of high-density population avoiding. Secondly, those who are likely to riding for a relatively longer distance will decrease bus use and increase cycling, which suggests that there is a competition between public bus and bike sharing in acceptable maximum riding distance. For those who think bus running slowly during holiday will not decrease bus use unless there are special travel fast line according the maximum transfer times travellers can accept, of course, the less likely to choose bus.

Thirdly, the effect of built environment factors on bike sharing use have been dramatic. The increasing bus frequency will reduce bike sharing choose compared with other travel modes, suggesting that there are competition between bus and bike sharing. Infrastructure and environment improving on road will increase bike using, such as security fence and road greenness, among this group factors, the safety fence will increase the sense of security, and the green plants along the road will clean air and bring a good mood to riders in the trip.

Fourthly, based on behaviour economics theory, personal psychological factors generate great effect on person with bounded rationality (Cialdini R B, 2010). Awareness of physical exercise, energy conservation, pursuing flexibility and riding culture inflection will improve the williness of the travellers to choose bike sharing. By contrast, altruism to offer seats for socially vulnerable group to achieve self-worth will enhance travellers’ willingness of using bus. At last, the effect of related information the travellers obtain on their travel mode choice behaviour, such as the price incentives on bike sharing using, will decrease bus taking. And inaccurate information of real-time arrival of bus may increase bike using, which all means a competition between bus and shared bicycle.

| Table2. Parameter estimates for Multinomial logit Model |
|-----------------------------------------------|
| variables                                      | Public bus | bike sharing | Public bus=bike sharing |
|                                           | coefficient | p-value | coefficient | p-value | coefficient | p-value |
| household vehicles                           | -0.79* | 0.09 | -1.3** | 0.05 | --- | --- |
| city level                                   | 0.67* | 0.06 | --- | --- | --- | --- |
| time of congestion                           | -1.23*** | 0.004 | --- | --- | -0.898** | 0.04 |
| health level                                 | --- | --- | -1.09** | 0.03 | --- | --- |
| maximum riding distance                      | -1.08** | 0.016 | 0.89** | 0.04 | --- | --- |
| departure time : holiday                      | -1.1*** | 0.008 | --- | --- | --- | --- |
| travel fast line                             | 0.31* | 0.08 | --- | --- | -2.249*** | 0.007 |
| carrying child or the elderly                 | --- | --- | -1.97*** | 0.001 | --- | --- |
| trip familiarity                             | -1.25*** | 0.001 | -1.07** | 0.04 | --- | --- |
| transfer times                               | 1.43** | 0.016 | --- | --- | --- | --- |
| bus frequency                                | --- | --- | -4.95** | 0.018 | --- | --- |
| distance between two                         | --- | --- | 0.89** | 0.03 | 1.07*** | 0.008 |
| transfer station                             | --- | --- | -1.51* | 0.08 | --- | --- |
| bike lane without fence                      | --- | --- | --- | --- | -1.935** | 0.03 |
| shortage of bike sharing at bus stations     | --- | --- | 2.19** | 0.05 | --- | --- |
| road greenness                               | --- | --- | 1.55** | 0.02 | --- | --- |
| awareness of physical exercise               | 0.95** | 0.03 | --- | --- | --- | --- |
| awareness of offering seat                   | --- | --- | 1.76*** | 0.01 | --- | --- |
| awareness of energy saving                   | --- | --- | -0.9* | 0.086 | --- | --- |
| relaxation                                   | --- | --- | 1.26*** | 0.01 | --- | --- |
| flexibility                                  | --- | --- | -0.92* | 0.09 | --- | --- |
| safety                                       | --- | --- | 1.85** | 0.02 | --- | --- |
| culture of riding                            | -0.9*** | 0.02 | 1.11* | 0.06 | -1.64*** | 0.04 |
| information to get riding disc               | --- | --- | --- | --- | --- | --- |
| information of real-time arrival of bus      | --- | --- | 20.61*** | 0.006 | 20.11*** | 0.004 |

*** indicates P<0.01, ** indicates P<0.05, and * indicates P<0.1.
4.2 Results analysis on cooperation
From the results of regression models, the longer congestion time is, the less cooperation between the two modes. This can be explained by the fact that there are fewer public bus options due to road congestion. The opening of travel fast line will reduce shared bike usage to decrease to the cooperation. It is natural that the shortage of shared bikes will reduce cooperation, and the number of intersections will have opposite effect on choice of bus + bike sharing result of high risk of traffic accident at cross-roads. And the incomplete information of real-time arrival of bus will decrease cooperation between bus and bike sharing, which may due to people’s tendency to avoid uncertainty (Ettema D, Timmermans H, 2006), they may shift to use shared bike along instead the cooperation shifted to the competition.

5 Discussion and implication
The aim of this study is to explore the factors influencing the travel mode choice behaviour, especially public bus and bike sharings, and then further explore cooperation relationship between these two modes. These findings will provide policy recommendations for urban transportation planners according to the demands of travellers. In return, the subjective psychological factors of travellers will imply the planners adopt guidance policy to make the whole urban transportation more sustainable.

Given the phenomenon of absolute congestion on the ground during rush hours and holidays, it’s essential to do the research about how to coordinate various travel mode and fully utilize the public space on the road, which relate to sustainable urban transportation development.

In order to improve the competitiveness of public transport, this paper simply puts forward four suggestions as follows. The relevant departments need to address the problems caused by bus system own in terms of those factors that negatively affect bus use: (1) develop pecial travel fast line, and give priority to public bus allocation of rights on the road to pick up speed during peak hour and holidays. (2) increase bus frequency in the section with high-density population to shorten the waiting time of passengers at bus stops. (3) provide more seats on bus and allocate passengers flow appropriately according to big data to make users feel comfortable. (4) make fully-covered and accurate real-time arrival information of bus available for bus users. (5) explore renewable energy for public bus.

As for promoting modal cooperation, the results of parameter estimates showed that the factor affecting choice of bus or bike sharing certainly will have impact on cooperation between these two modes. Therefore, the first step is to solve respective problems of shared bicycle system and bus. The paper put forward some suggestions for shared bike using as follows based on the estimated results: (1) properly plan infrastructure building, such as path width and security fence. (2) improve traffic safety at intersections by utilizing penalties for those who don't abide by the traffic regulations on roads by shared bicycles. (3) increase road greenness to attract more travellers to ride in leisure and travelling scenarios. The second step is to connect bike sharing with bus, some advises are as follows: (1) control the number and use of private cars. (2) evenly distribute the number of shared bicycles and regularly park bikes at a specific position, especially at bus stations, reducing unnecessary troubles for modes transfer. (3) incorporate shared bicycles into the public transportation system and implement cooperation with public transit by charging a discounted intermodal fare.

6 Conclusion
Bike sharing has experienced rapid growth across the globe, providing new options for mobility that are both independent and supportive of public transit. However, the use of shared bicycles also directly reduces the share of the public transport system and, to a certain extent, causes waste of public transit resources such as parking space, road traffic space, passenger transport efficiency, etc., which intriguing further exploration in relationship between public bus and bike sharing.

The SP experiment data in this study showed that although there is a complex competition and cooperation between shared bicycles and public transportation, especially buses, the medium and long-distance commuting is common so that the bike sharing mostly play an important role in replacing buses to connect with railway system. Therefore, in the context of metropolitan areas, the competitive relationship is more significant than the cooperative relationship between buses and shared bicycles based on all kinds of influencing factors. In return, effects of these factors on bus and bike sharing use will play good guiding roles in improving transportation infrastructure, formulating travel regulation and behaviour norms.

Generally speaking, the emergence of the sharing economy is a trend of social development. From the earliest car-sharing such as Didi mode in China to the current bicycle-sharing, it is actually a reflection of the sharing economy. The development of the public transportation system must adapt to this development trend in order to make better use of this economic model and promote sustainable and green development. It is indeed a challenge to synthesis and utilize the impact brought up by a new traffic mode in the current traffic system, which is already complicated and dynamic.

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