urban science

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Sharing and Riding: How the Dockless Bike Sharing Scheme in China Shapes the City

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Received: 4 July 2018; Accepted: 31 July 2018; Published: 9 August 2018

Abstract: Over the last three years, the dockless bike sharing scheme has become prevalent in the context of the boom in the sharing economy, the wide use of mobile online payment, the increasing environmental awareness and the inherent market demand. This research takes Beijing as a case study, investigates the users' characteristics, their behaviour change, and perceptions of dockless bike sharing scheme by the quantitative survey, and then analyzes the reasons behind it and how it has changed the residents' life in Beijing. This new kind of dockless shared bikes, with great advantages of accessibility, flexibility, efficiency and affordability, helps to solve the 'last mile' problem, reduce the travel time, and seems to be very environmentally-friendly and sustainable. However, with the help of interview and document analysis, this research finds that the shared bikes are not the effective alternative for the frequent car-users. Nevertheless, it also has numerous negative consequences such as 'zombie' bikes blocking the sidewalks and vandalism to the bikes. The public is also worried about their quality and safety, especially the issues of 'right of way'. How to coordinate and solve these problems is not only related to the future direction of the dockless bike sharing scheme but also to the vital interests of the general public. Therefore, it is important to emphasize that governments, enterprises, and the public participate in multi-party cooperation and build synergic governance networks to carry forward the advantages and avoid the negative effects of the new bike sharing system.

Keywords: bike sharing; sustainable mobility; sharing economic; urban studies

1. Introduction

In recent years, growing concerns over climate change, deteriorating urban environment and unhealthy lifestyles have placed more attention on sustainable transportation alternatives such as bicycles. The bicycle, compared to other kinds of vehicles, has many advantages for both cyclists and society: it is a low-cost, low-polluting, health-improving way to travel [1]. In light of these benefits, cycling has become a major component of visions of sustainable urban transport systems in Europe, supported by market-based instruments, command-and-control approaches, as well as soft policy measures [2].

China, like many of other countries, has experienced a rapid growth of bicycles from the 1970s to the 1990s. However, after the mid-1990s, bicycle usage steadily decreased as a result of economic growth, increased urbanization, expanded city areas and a gradually deteriorating cycling environment [3]. At the beginning of the 21st century, the Chinese government realized that excessive dependence on cars has led to serious environmental pollution and resource constraints. To preserve the environment and achieve a harmonious balance of economic growth, population, resources and the environment, the Chinese government put forward the new urban development mode of 'a resource-conserving and environmentally-friendly society', and had a major shift from fossil

fuels to renewable energy [4]. Nevertheless, a long history of bicycle usage in the country provides great potential for bicycles, a green form of travel, to be part of public and private transportation. Following the Chinese government's new approach, Chinese municipal governments have heavily subsidized the development of the Public Bike Sharing Program (PBSP) to encourage non-motorized transport and offer a flexible, convenient, and low-cost mobility option to the people.

Yang et al. used the real spatial location data of the public bicycle-sharing systems of Hangzhou and Ningbo in China, and discovered that the public bicycle-sharing systems can decrease the average trip time of passengers and increase the efficiency of an urban public transport network, as well as effectively improve the uneven level of traffic flow spatial distribution of an urban public transport network; they found that this will be helpful for smoothening the traffic flow and alleviating traffic congestion [5]. Zhang et al. found that bike-sharing systems have varying degrees of success based on the empirical study of five Chinese cities. The configurations which seem the most sustainable consider and integrate elements relating to transport planning, system design and choice of business model. PBSP, as a Product Service System, needs to be carefully developed to appreciate the quality and timely interplay between the physical design of the system and the provision of services being offered [6].

The first PBSP emerged in Beijing in 2005 when some touring-related firms started the bicycle rental operation to meet the needs of tourists, especially the overseas visitors who want to rent a bicycle to travel around Beijing. During the 2008 Beijing Olympic Games, the public bicycle rental market reached a peak. However, after one year, the public bicycle rental market encountered many problems. Some companies declared bankruptcy and were closed, others closed dozens of bicycle stations to reduce the operational costs. Some researchers summarized five reasons of failure of the first generation of PBSP in Beijing: unreasonable distribution of bicycle stations, lack of safety for cyclists, deteriorated conditions of public bicycle equipment, unattractive fare and inexplicit policy orientation [7].

One of the barriers that still hindered the traditional bike sharing services was the difficulty of access to docking stations [8]. Learning from the experience of PBSP, a successful dockless bike-sharing program may integrate the functions of docking stations directly into the shared bikes. In 2015, two start-up companies, Ofo and Mobike, initiated an innovative generation of fully Dockless Bike Sharing Scheme (DBSS) in China [9]. In mid-2017, the total amount of venture capital for the bicycle industry in China reached USD 2 billion, and more than 40 bike-sharing companies have been established, which makes the market tempting but fierce [10].

This new generation of bike sharing schemes is different from the traditional public bike system since it is easily accessible, flexible and cheap (Table 1). Before the existence of the DBSS, bikes needed to be docked at stations, whereas in the DBSS, bikes can be un-locked and paid for using a smartphone and can be picked up and left any parking area at users' convenience [11]. The DBSS becomes prevalent in the context of the boom in sharing economy, the wide use of smartphones, mobile Internet and online payment. Bike use dramatically increased within the recent years, when private companies started to combine digital technologies with sharing economy concepts. In July 2017, the total number of domestic shared bikes reached CNY 16 million, and the daily ride transaction of shared bikes reached CNY 50 million across China. The rapid development of the DBSS has created 100,000 new jobs in China [12].

Table 1. The comparison between the Dockless Bike Sharing Scheme (DBSS) and the Public Bike Sharing Program (PBSP).

Characteristics	Dockless Bike Sharing Scheme (DBSS)	Public Bike Sharing Program (PBSP)
Dock station	Dockless	Fixed docking stations
Location	Anywhere and can be found via apps	Near subway stations, bus stops and intersections
Usage	Scan the QR code with smartphone to unlock	Get a bicycle-rental card to unlock
Reservation	Can be reserved for 15 min	Cannot be reserved
Price	CNY 0.5~1 for 30 min	Usually free for the first 1 or 2 h
Deposit	Deposit can be returned anytime on apps	Refund deposit at the rental service branches

The DBSS has led a trend of 'green travel' in China. Based on the research, bike sharing in Shanghai saved 8358 t of petrol and decreased CO_2 emissions by 25,240 t in 2016 [11]. It seems that DBSS could significantly help China to achieve the declared goal in the Paris Convention of reducing the CO_2 emissions by 60–65% per GDP before 2030 [13]. On the other hand, DBSS with its great advantages of flexibility in short trips is just the one to deal with commuters' 'first mile/last mile' problem—the movement of people from a transportation hub to a final destination of the home or office. This new integrated transportation mode, namely the 'bike + bus/metro + bike' trip, has improved the efficiency of the traditional single type of vehicle mode.

The new generation of bike sharing services without docking stations is currently revolutionizing the traditional bike-sharing market as it dramatically expands in China and even around the world. However, many cities are not ready to welcome the mass of rubber and aluminum from blocking pedestrian walkways and piling up in the public space [14]. Though the DBSS is a fairly new trend, the concerns about the popularity, the benefits and potential harm behind it has prompted a hot debate among the public as well as the academic circle. However, there is still a gap between the descriptions of phenomenon and the assessment of the practice. It thus raises a pressing question—does DBSS, this new scheme, really help cities to move towards a more sustainable mobility mode?

In addition to the societal relevance, this study also has a scientific relevance. Firstly, although a range of empirical studies have already reported a wide variety of findings on bike sharing, it has often been argued that there are distinctive inconsistencies across studies due to study design limitation, measurement bias and cross-country variations. Particularly, a majority of research is drawn from the European and American cities, while very little research has been concentrated in Chinese cases with a rapid growth of PBSS [15]. To fill the gap in context-specific research, this paper takes Beijing as a case to investigate the bike sharing development in China. Secondly, there is a growing literature on the earlier breed of docked bike sharing schemes, there are very few critical academic studies of this new dockless bike sharing scheme [16]. This research seeks to contribute to social scientific debates on the new DBSS and its impacts. Thirdly, there is a lack of theoretical scientific knowledge and methods in existing research on DBSS. The current study of DBSS mostly uses the data provided by the operation companies, which include the basic bikes' and users' information plus GPS information about the route and parking place [11,17,18]. They normally focus more on the macroscopic usage of DBSS by big data mining and ArcGIS analysis. For example, Zhang and Mi discuss the environmental benefits from a spatiotemporal perspective, quantitatively evaluate environmental benefits of bike sharing using a large-scale bike-sharing dataset provided by the company Mobike, and estimate the impacts of bike sharing on energy use, carbon dioxide (CO_2) and nitrogen oxide (NO_x) emissions in Shanghai in 2016 [11]; Pan et al. conduct extensive experiments for hierarchical reinforcement pricing based on a real dataset from Mobike to propose a deep reinforcement learning framework for incentivizing users to rebalance dockless bike sharing systems [17]; Chang et al. take Beijing as a case study and present a framework design of the Faulty Bike-Sharing Recycling Problem optimization model to minimize the total recycling costs through the K-means clustering method that is used to divide the faulty bike-sharing into different service points [18]. Only Spinney and Lin studied the DBSS through a qualitative and societal perspective—by exploring the social, spatial and environmental relations produced by these new "hybrid mobiles", they explore the extent to which these systems represent

more economically reproductive 'transactional' or disruptive and 'transformational' modalities of sharing [16].

This study however derives from the users' survey and is supported by experts' interviews. It tries to investigate people's perception and attitudes, while at the same time exploring the behaviour change of people's travel mode engendered by these disruptive forms of bike sharing, and by using a mixed quantitative and qualitative method.

From the above, the overall research aims can be summarized as below:

- To explore the reasons behind the popularity of the DBSS in China and investigate the users' characteristics and their behaviour change and perceptions of DBSS;
- To explore and critically assess the contribution of DBSS towards sustainable mobility in Beijing context;
- To propose recommendations for healthier DBSS development and governance in the future.

2. Materials and Methods

2.1. Case Study

The identification of the case to be studied is largely dependent on the researcher's interest. In this research, Beijing is the suitable and typical case worth studying. Beijing is suffering from strong air pollution, which is a serious threat against the health of the residents and the environment. Beijing, with its 21.5 million inhabitants, is one of the most crowded cities in the world, and the huge population has exacerbated the problem. To assess the contribution of DBSS to the city's sustainability and analyze the potential solutions for cities to cope with the challenges of the new bike boom, a single case study is adopted for both methodological and pragmatic reasons. First of all, Beijing was a pioneer in the new bike-sharing approach—by September 2017, there were 15 Shared bike bicycle enterprises, which comprised 2.35 million shared bikes. In addition, the two biggest operators, Ofo and Mobike, both chose to locate their headquarters in Beijing [14]. On the other hand, in September 2017, the Beijing Municipality just announced a new regulation to encourage the development of a standardized bicycle sharing system, to implement the holistic governance and control of the DBSS providers, and to keep a dynamic balance on the quantity of shared bikes that have been put into the market.

2.2. Data Collection and Analysis

In this study, the data is generally from three main sources: documentation, survey, and interview. To achieve the research aims, different methods are used to collect the targeted data (Table 2).

The analysis in this study is based on the primary data gathered from survey, interview and secondary data from other documentation. Analysis of survey data tends to be through the use of a computer utilizing a number of statistical analysis software packages. In this case, SPSS is used for descriptive, analytical and contextual analysis. The in-depth interviews were digitally recorded and fully transcribed. Afterward, the analysis of the transcripts involved three stages: familiarization, thematic analysis, and interpretations. All the data enrolled the triangulation to verify the validity and reliability.

Table 2. Targeted data and collecting methods.

Data from Survey			
Users' Characteristics • Age • Gender • Income • Education • Occupation ……	**Travel Characteristics** • Commuting time • Commuting distance • Transport preference before and after the using DBSS ……	**Ride Characteristics** • Frequency of usage • Travel purpose • Travel length • Travel time • Reasons for using ……	**Users' Attitude** • Satisfaction of bikes, infrastructures, parking, safety, • Influence on life and city ……
Data from Documentation and Interview			
Companies' Data and Documentation • GPS location • Travel route • Travel mileage • Recycling and repairing • Policies and reports ……	**Interview with Planners** • The sustainability of DBSS towards city • The impacts of DBSS towards city • The potential coordinating way ……	**Interview with Community Worker** • The influence of DBSS on community • The responsibility of community • The coordination with other parties ……	**Interview with Bike Hunter** • The operation and organization of the bike hunters' group • Daily job and self-reflection • The difficulties and solution ……

2.2.1. Survey

The survey in this study has four parts, and the full Internet survey is used to gather data. Firstly, the classification questions, namely the 'personal' section of the survey. Demographic information such as age, gender, income, education and occupation are collected in the beginning of the survey. Secondly, the survey asks respondents lifestyle and travel characteristics, for example the commuting time and distance, the transportation they choose for commuting, chores and entertainment. In this part, people need to answer the transportation mode they normally choose before the DBSS appeared and after to evaluate the behaviour change. Thirdly, the data of ride characteristics are collected, including the trip purpose, frequency, length and other related figures when people use the DBSS. Finally, the attitude scale form helps to assess the opinion and perception of users towards DBSS. There are also several open questions in the last part to give respondents greater freedom to answer in a way that suits their interpretation.

This study uses a non-probability sample, because the statistical accuracy may be less of a concern than being 'fir for purpose'. Purposeful sampling occurs where a selection is made according to a known characteristic, in this case—the Beijing citizens who regularly use the DBSS. Whilst the population in Beijing and the DBSS users are widely distributed, snowball sampling and convenience sampling are also helpful when obtaining substantial survey data. As for the sample size, in order to be able to measure differences or variability in the sample and to use these findings as estimates of the population, 260 samples are selected in this research. The number is calculated by the online sample size calculator, with the confidence level of 95% and confidence interval 6%. A population of 11,000,000 is cited by the registered DBSS users in Beijing in August 2017 [19]. The overall background range of samples is comprehensive and balanced, however the number is relatively small compared to the residents in Beijing, which might cause some bias of the research outcome.

Due to the limited time and budget, this study uses an online survey to collect data on DBSS users. There is a pilot survey phase before the formal distribution. Once the survey design was completed and prior to distribution to the sampling frame, a pilot study was undertaken on 15 people. The time-span of respondent recruitment is 2 weeks. In this study, once the recruitment postings had been made, the survey administration and recording of responses was self-running. The DBSS requires smartphone and online payment for operation, thus nearly all the users are smartphone holders, which means they could receive the link of the online survey by smartphone. Considering the above reasons, the survey is posted in the social media groups, and public pages, thus people who are interested in the topic, and satisfy the filter criteria of purposeful sampling could fill in the form

whenever and wherever it is convenient. However, since the sample size is relatively small and the time-span is relatively short, the outcome may have some negative bias.

2.2.2. Documentation

In this study, both official documents and private documents are reviewed. The documentation in this research is from media and news reports relating to the growth, investment and impacts of DBSS in Beijing and China more broadly. For example, Mobike, one of the major companies that provides DBSS service, together with some academic institutions, has published certain reports that include a lot of useful information and users' travel data. Policies, government guidelines, as well as the data about infrastructures and transportation are collected from the government's yearbook and official website. For example, the various guidelines both from national government and Beijing municipality are carefully reviewed [20–24]; Meanwhile, the White Papers published by the Mobike company also contributed to this research [25,26].

2.2.3. Interview

To ensure the authenticity and availability of the information, two planners (experts in transportation), one local community worker from subdistrict office and one Mobike Hunter from the—Mobike Hunter's Volunteer Network agreed to participate in the semi-structured interview. The participants were asked about the problems they faced with cycling and development of the dockless bike sharing system in the city (see Table 2). Planners and community worker interviews are about their insights on the DBSS and its impact on the city's sustainable development and the potential approach for cities to cooperate with this new trend. The interview of Mobike Hunter is related to the research potential for solving the problems that DBSS has brought. Unfortunately, the operation companies refused to participate in the research, which means the perspectives from the market are missing.

2.3. Ethical Considerations

The topic of this thesis related to people's behaviour and attitudes, which did not involve any illegal behaviour. Ethical issues are carefully considered in this thesis. As regards the recruitment procedures, the target group in this project did not include any vulnerable groups. The project was spread by social media and conducted online. Meanwhile, all the interviewees who participated in the survey were asked for permission to conduct the interview and questionnaires. Besides this, all respondents were informed that they can withdraw from the study at any time and that the survey is entirely anonymous. The participation is voluntary and the data will only be used in this thesis. No observation was conducted. There was no potential risk for any respondent, neither physical nor psychological.

3. Results

3.1. Findings from the Survey

A total number of 260 survey respondents have been selected. Women and men are equally represented. Fifty-two percent of the participants are young (18–30), 48% are middle-aged (30–60) and there are very few senior participants (60+). The result implied that the DBSS users are popular in all age groups, particularly the active younger groups. Meanwhile, the majority of respondents had an academic background (75% had a bachelor's degree or above). Referring to the average monthly income in Beijing, which is CNY 7706 based on the Beijing Municipal Human Resources and Social Security Bureau, the participants were situated among various income levels apart from the no income group (15%); 44% had lower than the average wages, and 41% had higher wages than the Beijing average monthly income. As for the occupation, most of them are students or staff in public institutions or enterprises and professional workers who do not do too much manual labour. As for

the participants' commuting figures, it can be observed that half of the participants commute under 40 min per day, and 58% commute less than 10 km (see Figure 1).

The survey shows that 38% users are frequent users of DBSS, and only 14% of participants never use the DBSS. People choose DBSS most because of its convenient and time-saving characteristics. For these non-users, however, their reasons to refuse the DBSS are mostly about their daily needs: to deposit money and to retain private information.

In most circumstances, the shared bikes are used for a short time and distance interval. Sixty percent of respondents finish their trip in less than 10 min and 91% in approximately 20 min. Two thirds of users use DBBS for 1–3 km distances. This means that the majority of the users use DBSS for their last mile of travel. The most common cycling time is 7:00–9:00 and 17:00–19:00 for commuting which equals to the rush hour in Beijing. Two thirds of trips are for commuting and one third is for leisure and everyday chores. It is also revealed that hybrid transportation modes were popular. Nearly half of the users always transfer to other modes of public transportation such as the metro (89%) and bus (54%).

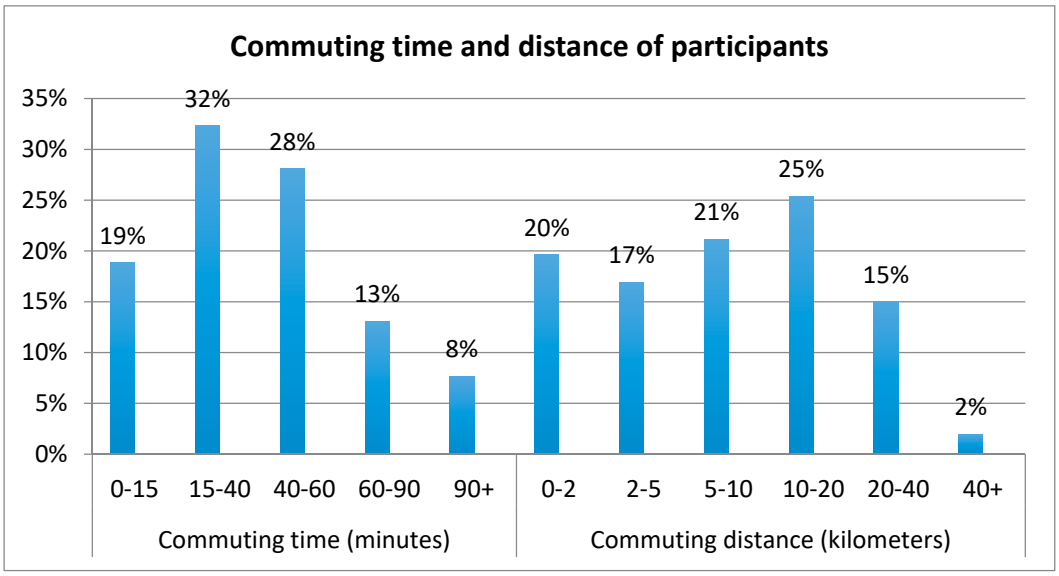

Figure 1. Commuting time and distance of participants.

3.1.1. How Does the DBSS Change People's Lives?

In the survey, people are asked to choose their transportation mode in the city for different purposes before and after the DBSS appeared. From Figure 2 below, we could find that the change of car-use and motorbike-use is not significant before and after the DBSS appeared. The usage of bikes as the mode of transportation for commuting purposes is doubled; meanwhile walking and the usage of public transport have slightly declined. The transportation mode change of chore purpose trip and entertainment purpose trip are similar to the commute purpose, which has the same increase in terms of bike use (more than doubled).

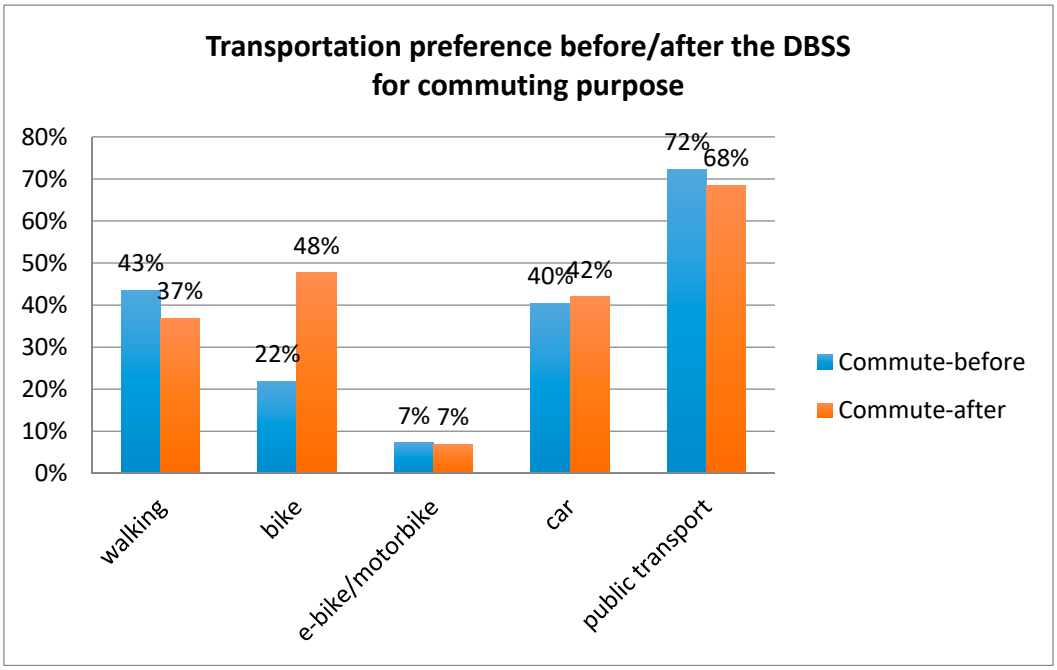

Figure 2. Transportation preference before/after the DBSS for commuting purposes.

'The cost of bike sharing is much lower than either buying a bicycle or taking the bus or taxi. It is more economical for me to share the bicycle, and at the same time, it is also beneficial to reduce the risk of it being stolen.' (Participant A, reflected from the survey)

However, most users indeed agree that the DBSS has changed their life (66%). Changes are reflected in the following aspects. Forty-four percent of users agree that the DBSS has extended their travel distance range, and users agree that the DBSS has reduced the time restriction (57%) and saved the travel time (76%) for going out. At the same time, 58% think the DBSS has reduced their travel budget.

3.1.2. Users' Satisfaction with DBSS in Different Aspects

Though the general satisfaction is relatively good (Figure 3), the DBSS companies need to pay more attention to the quality of the bikes since 30% of users express low or very low satisfaction about it. As for the factors that lead to dissatisfaction, 45% of users choose the 'pedals or the chain does not work properly', 35% blame the 'unsuitable seat', 35% reflect that 'the handle bar or the break doesn't work properly'. The channels for reporting the errors also need to be improved. Because over 63% respondents always see the broken or wrongly-parked shared bikes on the street, only 22% choose to report the error every time. Parking is another severe problem with which users are not satisfied.

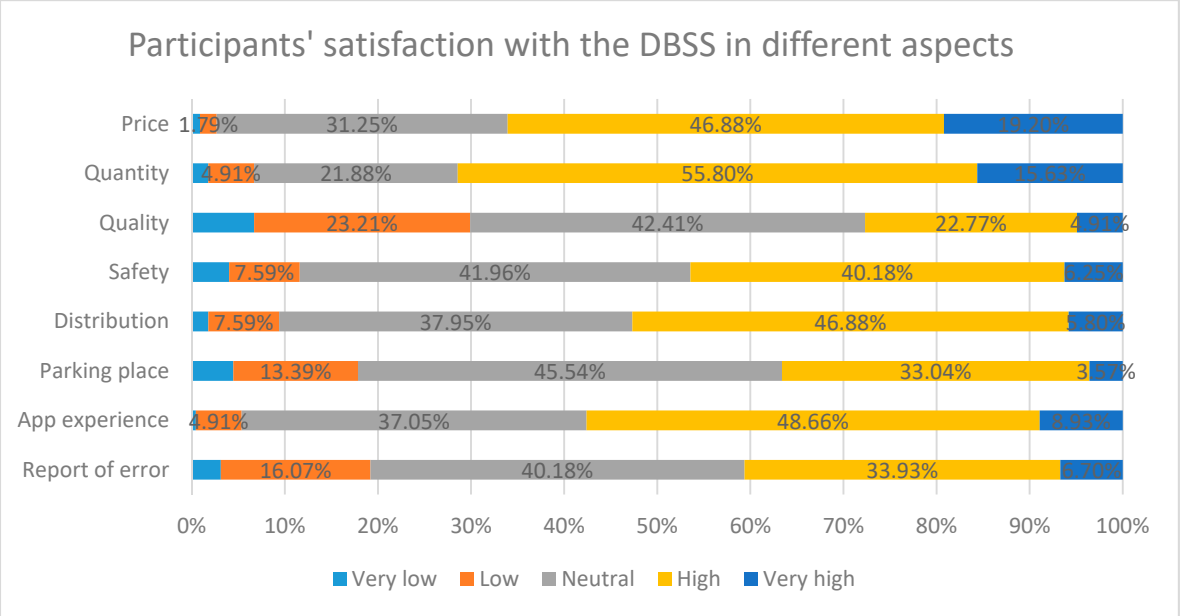

Figure 3. Participants' satisfaction with the DBSS in different aspects.

3.1.3. Users Perceptions towards DBSS in Different Aspects

> *'For…short-distance travel, the advantages of shared bikes are the flexibility and speed. Compared to driving or taking a taxi or bus in…rush hour in…large- and medium-sized cities, riding a shared bike could apparently save you time.' (Participant B, reflected from the survey)*

> *'I don't need to look around for a parking place while finally arriving at my destination, because these bikes are "floating" without any dock. And I can always ride a bike when I'm too tired to walk while enjoying the street views at the same time.' (Participant C, reflected from the survey)*

Before the DBSS, 52% of users thought the previous transportation could fulfil their needs, while after the launch of the DBSS, the number increased to 70%. Nevertheless, only 44% of users indicate that the bicycle lanes in Beijing could fulfil their needs, and for bicycle parking lots the number is even lower (40%). Sixty-four percent of users call for a special parking place for shared bikes, and the hottest spots they mentioned are around metro/bus stops, neighbourhoods, office buildings and shopping malls. People are overall optimistic in that more than 90% of participants think the DBSS helps to solve the 'last mile' problem; 65% agree it helps to improve the environment; 64% agree it mitigates the traffic congestion of the city.

3.2. The Contribution of DBSS towards Sustainable Mobility in Beijing

3.2.1. Environmental Impact

As reviewed in previous research studies, bicycles have their own advantages, especially in regard to their environmentally-friendly characteristics [26]. Therefore, as it stands, the DBSS should have helped with the improvement of the urban environment. However, the results of the survey and interviews raised some doubts about this assumption.

First of all, many people considered that the DBBS increased the cycling rate in the city and that it seems reasonable that fuel consumption and greenhouse emission have been reduced. Meanwhile, the DBSS companies also claimed that the DBSS has made great efforts in saving energy, reducing greenhouse gas emissions and saving the urban space [25].

> *'I helped the Mobike to conduct the research on Mobike White Paper. However, the company used their own conversion method and their users' data to write the Mobike White Paper. They simply replaced the*

riding mileage with the driving mileage, and advertise how they contribute to the environment based on this figure (see Figure 4). This calculation is not scientific and reliable at all. . . because the hypothesis that people change their transport from car to shared bikes is not always truthful.' (Mr. Wang, Planner)

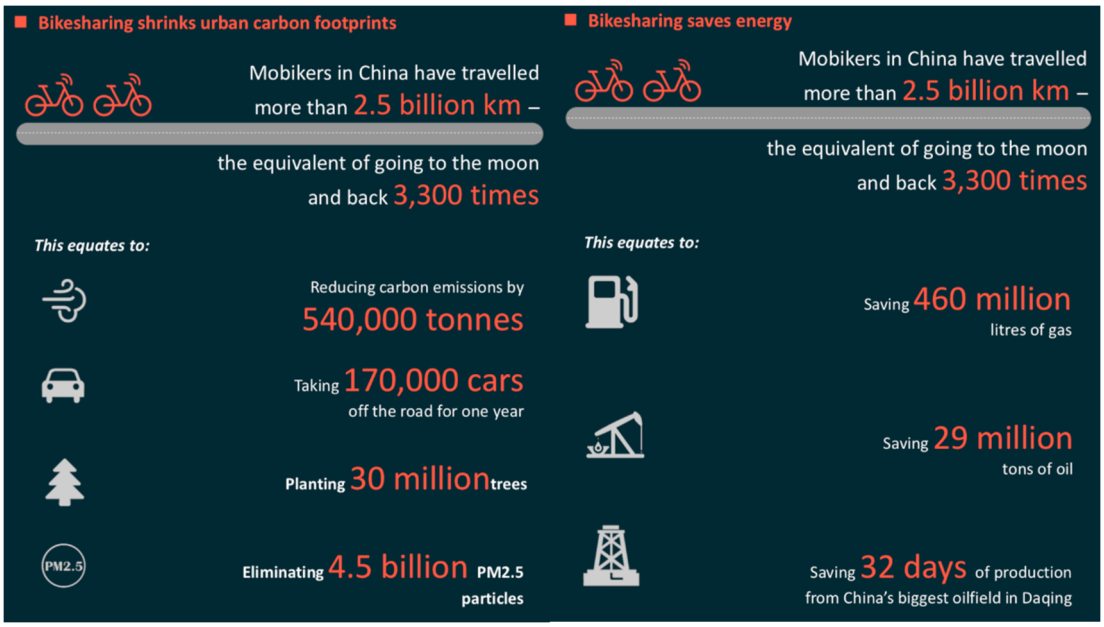

Figure 4. The statistics of bike sharing and its equitation to resource and environment data in Mobike White Paper [25].

The evidence can also be found from the survey—the results did not show that the residents replaced cars with bikes. From Figure 2, we could find that the change of car-use and motorbike-use was not significant before and after the DBSS appeared. The usage of bikes as the mode of transportation for commuting purposes is doubled; meanwhile, walking and the usage of public transport have slightly declined. The transportation mode change of chore purpose trip and entertainment purpose trip are similar to the commute purpose. This might imply that the DBSS is an additional transportation option for citizens to use, but it is unrealistic, at least in the short term, to control the usage of cars only by DBSS.

There is another critical voice arguing that the DBSS is not environmentally sustainable because it is neither a 'sharing economy' nor a 'circular economy'. The difference between the so-called 'bike-sharing' and the traditional sharing economy is that there are no spare resources in the shared bike model. All the bicycles are bought by the DBSS companies to meet market demand, which is different from the original intention of the sharing economy [27]. Moreover, some experts believe that the start-ups are too busy chasing territory and investment to focus on providing a good service: 'You see thousands of bikes parked everywhere around the city and many are not working because nobody takes care of them—the city's beauty has been destroyed' [9].

'Sometimes, government just drags away the wrongly-parked shared bikes to the shared bike. . . landfills without any warning. And if companies want to get these bikes back to the normal market, it is hard to negotiate with the government because of its low efficiency and high cost. Companies also pay more attention to the quantities rather than the qualities in the initial phase, because they need to occupy the local market and expand. . . fast. So those lack-of-care bikes become cities' foundling.' (Mr. Wang, Planner)

After some companies exit the market, the shared bikes they put on the street are abandoned and cause significant resource waste and environmental pollution. Bike vandalism and theft have

also become a recurrent issue. Vandals have often targeted the bikes, placing them on trees or even destroying them by setting them on fire. Furthermore, currently, there is no efficient way to prevent these criminal activities. As Spinney and Lin discussed, 'on a conceptual level, the abandoning of bikes anywhere on the streets is emblematic of the maximization of private utility (saving time and effort) over collective utility (the ability of other users to easily use the public realm)' [16].

3.2.2. Economic Viability

Generally speaking, these new bike sharing services are a more advanced innovation with a valuable economic impact on cities' sustainable transportation development. The DBSS has expanded the scope of public transport services, allowing residents to choose from a wider range of lifestyles and work areas.

In China, the new DBSS, different from the traditional public bikes, is provided entirely by the private companies. The market gives the DBSS inherent advantages—efficiency. The DBSS compares to the public bikes provided by local government or joint venture between the government and private sectors, and provides a cheaper, more convenient, and more comprehensive service.

The survey result shows that 65% of the participants agree that the DBSS has changed their daily life; 56% think the DBSS reduces the time restriction for going out, and 76% think it saves traveling time. Meanwhile, more than half of the participants think the DBSS helps them to save on their traveling budget. The DBSS also has the obvious advantage of easing traffic congestion. From the report of Mobike White Paper [25], in Beijing, for trips shorter than 5 km, 92.9% of trips are quicker by shared bike plus public transport; for trips longer than 5 km, 23.7% of trips are faster by shared bike plus public transport.

In most cases, the DBSS is a good solution to the 'last mile problem' and has the significant feature of connecting to other public transportation. In Beijing, 81% of the Mobike trips start at the bus station and 44% of trips start near a metro station [25]. The DBSS has expanded the service scope of the metro stations and facilitated metro services to more citizens. If we set the distance range when the house rent is reduced to 80% as the so-called 'new metro area', the so-called 'new metro area' will extend from 900 m around the metro station to 1650 m from the year of 2013–2015 to 2016–2017 [28]. The expansion of this service range has naturally expanded the scope of the 'new metro area' and structural changes have taken place in the urban rental housing market. Furthermore, the DBSS as a basic transport facility spatially reconstructs our urban structure, which in turn affects our lives in more ways.

However, from the perspective of the DBSS companies, is this model economically sustainable? As an enterprise, to put shared bikes into the market is not a purely public welfare investment, and the final point is still for profit. In the beginning, the huge initial investment does not affect the recovery of its cost. Just like the previous car-hailing app, with the crazy money-burning mode, these new bike sharing apps quickly occupy the market. Most bike sharing apps require paying the deposit as a credit/mortgage to rent the bike, which constitutes a small part of the capital return. The bike sharing apps also bring web traffic that will attract advertisements. Moreover, the large-scale production and technological upgrade of the shared bikes reduces the production and repair cost.

> *'The companies are not about…sustainable transport, they are primarily about data mining. When the companies found that they cannot manage the data, then the investment is just pull[ed] out. The companies' actual business model itself is not sustainable and profitable. Operators intend to use the data to reshape the relationship between themselves and the municipality in ways that move further away from flat and cooperative power relations to more uneven relations.' (Mr. Spinney, planner)*

From an explosive growth at the beginning of the year, to a series of bankruptcies by year's end, 2017 witnessed a roller coaster of China's bike-sharing business during the ups and downs. The industry boasted almost 60 bike-related start-ups over the last 18 months; nevertheless, by the end of November 2017, at least six well-known bike-sharing start-ups had shut down, and more than RMB 1

billion (USD 150 million) in deposits could not be refunded to users [29]. In the long run, with the wide spread of the new business mode, the recovery of funds is quite substantial. Hopefully, by optimising the cost and mining profit-points, bike sharing companies will gradually meet the profitability.

3.2.3. Social Profitability

From the social sustainability perspective, the DBSS gives residents another opportunity to go anywhere, anytime they want to go, without thinking about the long walking distance. This increases residents' frequency of travel and frequency of exchanges, improving the vitality and utilisation of the urban space. It also helps the health of the residents. The positive impact of the DBSS is to improve the access and reduce the exclusion, but the negative impact is that the DBSS has been shown to be relatively unequal and unsafe.

The DBSS has markedly improved the accessibility from door to door. After the introduction of the DBSS, users reported a decline in auto-rickshaw trips of 53%. The illegal auto-rickshaw is a common transport to deliver people from the metro station to their home. They are widely practiced despite repeated attempts by the government to stamp them out. Just take one instance of a metro station in Beijing, in spring 2016, just before the emergence of the DBSS: there were 200 auto-rickshaws, drivers each completing 40+ trips and earning up to 200+ RMB per day. However, after the growth in popularity of the DBSS, just 50–60 auto-rickshaws remain, and 70% of unlicensed drivers have changed jobs [25].

The inequality can be found both in terms of age and income. The senior citizens are hardly engaged in the DBSS, because the service is entirely based on the smartphone and online payment, and many older people do not have access to these new technologies. The relationship between income level and frequency of DBSS cycling was investigated by means of a regression test, and there was a strong correlation between the two variables ($p < 0.01$). This means that no-income or low-income groups tend to use the DBSS more frequently.

Safety is another big issue for the DBSS. Seventy-seven percent of respondents think that the drivers do not have the concession for riders, and they feel unsafe while riding the shared bikes. At the same time, many pedestrians also feel their walkways have been invaded by the moving or stopped bikes. Seventy-two percent of participants agree that the parking disorder has become the eyesore of the street and made the city messy, while 61% consider the shared bikes to take too much public space.

> *'In our sub-district, most streets are Hutong, so the alleys are very narrow. If the shared bikes are parked in the Hutong community, the streets will become even narrower. The bikes invade the residents' car-parking lots and walking pedestrians, and residents are angry about it. So, we have to hire the people from the property management company to clean up the inner Hutong, move the shared bikes into the vacant places, or at least put them in order.' (Ms. Sun, Community worker)*

There has been a major issue about the 'right-of-way' since the emergence of the DBSS. Ideally, motor vehicles, non-motor vehicles, and pedestrians should go their own ways, enjoy their respective rights in the corresponding areas, and other traffic participants should not infringe them. However, over the years, Chinese cities' urban planning has always placed the priority on car traffic. As motor vehicle ownership continues to grow, non-motorized vehicles and pedestrian access are severely squeezed. Many cyclists have negative experiences while riding the bikes. For example, there is a lack of isolation between motorized and non-motorized lanes, resulting in vehicles often passing by others' lane. Due to the limited place for riding, many cyclists have to ride on the sidewalk [30]. The mutual disrespect has led to chaos on the urban streets.

4. Discussion

The DBSS entered the public view at the end of 2016. Afterwards, it has become part of public transportation and public facilities. Due to low technical barriers, shared bikes have experienced savage growth in less than two years. Nevertheless, the DBSS comes with various disputes and

queries. Nowadays, a large number of shared bikes with disorderly parking, serious damage and the over-supply has become a new urban management issue. Some cities have already begun to issue policy documents. However, this complicated problem still faces the challenges of refined management and scientific decision-making.

4.1. Government: Infrastructure and Regulation

According to the statistical data from the Beijing traffic department, the number of dockless shared bikes in Beijing soared from approximately 700,000 to 2,350,000 in four months from April 2017 to September 2017 [17]. However, problems such as disorderly parking, quality and safety have restricted the development of the industry. The lesson is that to avoid the 'tragedy of commons' and uncoordinated individualistic action in a transport network, we need the government interference [31]. The DBSS, as a 'disruptive innovation', does not absolve cities from the principles of sound city planning, street design, and realising the value of public spaces.

Due to historical reasons, the Chinese-style urban space and traffic planning mode of 'wide roads, big blocks and sparse roads' has been fixed [5]. Bicycles were regarded as inefficient mobility in the past, thus the transport planning did not pay much attention to the design of the bicycle infrastructures and facilities. However, with the rapid growth of the DBSS, the preparation of special plans for bicycles needs to be put on the agenda as soon as possible to ensure the construction of bicycle facilities. In the planning process, local authorities should set a clear quantitative target with the data support, and solve the specific problems faced with focal points by stages.

On the other hand, the government also plays a vital role in investment of bike infrastructure and supporting facilities such as bike lanes, parking lots, and bike signals to make citizens feel safe and comfort while cycling. Bicycle infrastructure construction needs to focus more on the daily travel environment in the city, especially cyclists' rights, dangerous points, and end-breaking roads, to achieve greater effectiveness.

> *'Sometimes, our government is too slow to react when facing a new disruptive innovation. They are afraid of changing, and sometimes shirk responsibility when something goes wrong. The lack of regulation and attention caused the barbaric growth of DBSS in the beginning and caused numerous problems that the government can no longer ignore. However, DBSS start-ups might lose their strength due to the governments' rough control and management. The DBSS is an insightful reflection for the contemporary urban planning and governance in China.' (Mr. Wang, planner)*

The Chinese government issued guidelines in August 2017 by the Ministry of Transport to regulate DBSS services, including forbidding children under the age of 12 from using the shared bikes; operators have to buy insurance for users; customers need to register with their real name, etc. [32]. On 15 September 2017, the Beijing Municipal Commission of Transport [21] released the 'Guidance for the development of standardized sharing bicycles in Beijing (Trial)'. Based on extensive investigations and studies and with the actual conditions in the municipality, the administrative departments of various districts, industry associations and DBSS enterprises have formulated the 'Technical Specifications for Bike Sharing Systems Technology and Services' and the 'Technology Guidelines for Bicycle Parking Area Settings' [23]. The policy documents provide a comprehensive, detailed, and solid policy guarantee and normative guidance to encourage the healthy development of the DBSS. Under new changes, the local Beijing government will order bike-sharing companies to be regulated and supervised by municipal authorities. The firms will also be made to pay accident insurance for users.

> *'It is not enough to publish these regulations. What is more important is how to implement them and supervise them.' (Mr. Wang, planner)*

4.2. Companies: Maintenance and Cooperation

The DBSS companies are now facing the trouble of the vicious competition within the industry. As for the current shared bike model, we can hardly see the improvement in bicycle utilisation efficiency. Instead, many companies mass-produce new bicycles and put them on the market. This commercial competition among companies is merely to expand the market and squeeze out other competitors. It has deviated from the good intention of 'sharing'. As a result, the number of bicycles is bound to significantly exceed the Pareto equilibrium level [33]. It could not improve the utilisation efficiency of social idle resources but causes a tremendous waste of resources. Recently, six out of 30+ operators recently went bankrupt, which might be a signal of the bubble bursting. Many of China's shared bike users have fallen as victims of defaults on their deposit refunds, after the operators went bankrupt. No party has claimed responsibility for refunding public deposits. From the survey, it can also be found that 70% of respondents think the providers could not maintain the shared bikes on time and caused an enormous waste resources.

Previously, some DBSS companies found that compared to repairing the bikes, producing new bikes was even cheaper. For this reason, they would rather let the 'zombie bikes' spread on the street and blindly produce new bikes [34]. The new guidance released in September 2017 clearly defined the standard on the shared bike recovery and maintenance. This prompts enterprises to regularly recondition the shared bikes and keep the shared bikes' serviceability rate above 95%. Shared bikes should generally be put in use for three years and then they should be updated or scrapped; DBSS enterprises should own or rent parking spaces to meet the needs of vehicle turnover and maintenance [21].

Beijing has also controlled the total amount of shared bikes in the city. The promulgation of this policy precisely led enterprises to devote more energy and investment to maintenance and management rather than manufacturing. Thus, some experts believe that if companies adjust their business focus to the quality and maintenance of the bikes, the overall burden will not increase too much.

> *'It's good to see companies start to share their data with institutions for research purpose, because they are valuable for transport planning. But the business model is about mining and selling the data. So, I'd like to see more cooperation between companies and government, though I think government should buy it. However, privacy is a big issue when using this data.' (Mr. Spinney, planner)*

On the other hand, the result revealed that there is fear of social exclusion in the current DBSS; to include marginalised low-income groups who cannot afford smartphones, those who cannot work with smartphones or those who even prefer not to have smartphones, the DBSS requires more comprehensive software. New tools such as fingerprint recognition programs or urban transport cards can help.

4.3. Citizens: Culture and Participation

Education and various activities could help to encourage good behaviour and cultivate a cyclists-friendly environment. These can be initiated by the government, market, civil society, or a combination of all. It is not enough to rely solely on infrastructure to enhance the attractiveness of bicycles. Bicycles are closely linked to the social symbolic effect and the level of income. With the rise of residents' income levels, bicycles often embody the 'cheapness', which hinders the social acceptance and popularity of bicycles. We also interviewed some non-users of the DBSS and asked them why they rejected this service. Many of them said they did not know how to ride the bikes or that the bike is not a need in their life. Therefore, to encourage more people to cycle and to enable the cyclists to feel proud and satisfied as the car groups, large-scale publicity and education need to be carried out, so as to change people's view and make the bicycle become a part of the daily life style and the organic component of the city image. On the other hand, to guide the safe and right cycling/driving behaviour, and create a bike-friendly environment, schools, NGOs and local communities could help with the supervision and education.

For instance, the vandalism acts towards shared bikes led to the formation of a spontaneous civic group—'bike hunters':

> *'We use the APP GPS information to retrieve those illegal placed, abandoned, or stolen bikes. By reporting the violations of out-of-service or damaged bikes through the APP, the bike hunters could gain some rewards and at the same time, assist the orderly operation.' (Mr. Zhao, Mobike Hunter)*

Moreover, some shared bike operators have already set a credit system to encourage a better behaviour by rewarding users' credits for reporting broken or illegally parked bikes, and demerits for correspondingly bad behaviour. If your score drops too low, your next ride could become much more expensive [35].

> *'We regard bike hunting as a treasure hunting game. We enjoy the procedure of finding the stranded and damaged bikes, reporting them. It seems that we could contribute to the urban environment and society in our own way. The reward from the APP is not the main reason for us. The hunters in our volunteer groups become good friends and even become couples.' (Mr. Zhao, Mobike Hunter)*

4.4. Hybrid Governance

The national guideline put forward must adhere to the principle of multi-party governance and give full play to the joint efforts of the government, enterprises, social organisations, and the public. There must be coordination on three levels to achieve the continuous innovation for the DBSS [36].

- Synergy of the transportation mode

The DBSS alone itself cannot achieve the revival of bicycles. To promote the bicycles, the holistic green traffic solution should be provided to the public through the optimization of the connection and integration between the bicycles and various public transports.

> *'Many Chinese cities have issued guidance on the regulation of shared bike services, setting up a "black list for riding", piloting geo-fences, planning of banned parking areas, and enforcing real-name registrations to standardise the development of shared bikes, but with little success. Cycling brands have responded with the introduction of their own governance, such as developing geo-fences and artificial data platforms, etc., which have certain results in the short term. In the long run, if there is no unified control and standard, old problems cannot be eradicated. Therefore, a unified management governance system platform should be established to achieve accurate management of bicycle placement and operation.' (Mr. Wang, planner)*

For example, local authorities could incorporate the infrastructure investment with private sector companies. In the past, each DBSS company was basically independently managed and did not communicate with other players. As a result, the number of bicycles in the parking area was excessive and not properly divided. The establishment of a systematic DBSS management platform could enable the unified management of different brands of shared bikes. Its back-end system platform can also be open to all DBSS companies. In this way, shared bikes can be put into places where people gather and flow, such as bus stations, large squares, and stations near subways. If the number of bicycles exceeds the standard or the bikes are in short supply, they can use the backstage management system to conduct scientific and directional and effective operation and maintenance.

- Synergy of information

It is also helpful to promote comprehensive research on multi-source multidimensional data (open data, data sharing and public crowdsourcing data). Combining the traditional data and new data could support the process of decision-making.

Since according to the new guideline, all shared bikes have to be equipped with the GPS chips, the companies could share their transportation data on where people ride their bikes to, and where they park. With the help of the empirical data, the government could make a better decision on where

to build the new bike tracks, parking lots and public realm improvements [37]. In practice, Mobike and the Beijing Institute of Urban Planning and Design have signed a cooperation agreement. The big data will support the planning of Beijing's pedestrian and bicycle lanes during the 13th Five-Year Plan period. It will also assist with the planning of parking lots and parking spots and select and support Beijing 3200 km bike lanes' construction [38].

- Synergy of participants

Encourage all stakeholders including enterprises, government, the public, social organisations and so on in the process to achieve the win-win cooperation.

> *'We have different WeChat groups to discuss how to improve the dockless bike sharing system in different cities. There are officers from the Mobike Company, experts, users, and general people who are interested in helping with the issues in this online discussion group, so that our voices can be heard by the company. We also submitted our opinions and suggestions to relevant departments of city government, at the stage of releasing the trial requirements for comments. Actually, our final goal is that, one day in the future, we won't have any bikes to hunt.' (Mr. Zhao, Mobike Hunter)*

The participation of the public in urban DBSS management can, on the one hand, improve the public's awareness, quality and ability of democratic participation, self-management, and self-service; on the other hand, it can also promote the transformation of urban government functions and ensure the democratic and scientific public decision-making. It is conducive to the construction of a public service-oriented government that combines the concepts of responsibility, service, and the rule of law. In addition, the public participation in management also facilitates the implementation of government policies and accelerates the standardisation of the DBSS [39].

5. Conclusions

5.1. Brief Summary

With the emergence of the sharing economy, the popularity of the mobile payment, the environment awareness and the inherent market demand, the DBSS has led a trend of bicycle revival in Beijing, which is becoming a role model for all of China. These new kind of dockless shared bikes with great advantages in terms of flexibility during short trips are just the ones that could solve the commuters' 'last mile' problem. However, people are still worried about its safety and quality. Considering sustainability criteria, the DBSS was expected to have positive impacts on the reduction of greenhouse gas emission, elimination of pollution and health risks. However, the result of the survey shows that the shared bikes are not an alternative for the frequent car-users. Nevertheless, it has also yielded negative consequences such as blocked sidewalks and vandalism of the bikes. Oversupply has led to graveyards of bikes, and deep concerns about quality control, maintenance, and management of these systems. If there is no efficient way to avoid the bad treatment towards shared bikes and abasement of public space, it may be more of a curse than a blessing. Moreover, though the DBSS has increased the accessibility within the urban mobility framework to a great extent, the seasonal and tidal phenomenon calls for a more efficient way to dispatch and distribute the bikes. Furthermore, the business model of the DBSS companies seems to be not very sustainable or profitable. The public is also worried about their quality and safety, especially the issues of 'right of way'. How to coordinate and solve these problems is not only related to the future direction of the DBSS, but also related to the vital interests of the general public. Therefore, it is the general trend to emphasise that governments, enterprises, and the public participate in multi-party cooperation and build synergic governance networks to carry forward the advantages and avoid the negative effects of the new bike sharing system.

The city government should improve the construction of the bicycle traffic network, standardise the parking place setting of bicycles, and strengthen the supervision and law enforcement of illegal activities. Operators should implement the responsibility of DBSS parking management,

popularise and apply technologies such as geo-fencing, take comprehensive measures such as economic rewards and punishments and credit records, and guide users to regulate parking. At the same time, it is important to strengthen the publicity and education to guide mutual respect among drivers, cyclists and pedestrians through public service advertisements, theme education and volunteering activities. Users themselves are encouraged to enhance their awareness of the cycling etiquette, abide by traffic regulations, and abide by social ethics. The three-level coordination, namely the synergy of transportation mode, information and participants is recommended for the DBSS's future healthy development and efficient hybrid governance.

5.2. Limitations and Recommendations for Future Study

In this research, since surveys constitute a general method for collecting large amounts of data, profound and comprehensive views from specific users are lacking. The online sampling and distribution method may also cause the bias in this research. Future research may fill the gap by conducting in-depth interviews with various background users and generate more ideas from their perspective by qualitative methods. Moreover, though the actual performance of DBSS is being criticised assessed in this research, there are still many issues that had not been solved prior to evaluating the DBSS's sustainable mobility. For instance, directions for further studies may include the research about the quantified index, which could measure the performance of the DBSS towards sustainability in different cities.

In this research, only four interviewees agreed to join the research, and representatives from companies or local authorities are excluded. So, the research lacks direct views from the government and company perspective. Thus, more detailed operations and management advice needs to be proposed in future research. For example: how regulations could be improved and implemented more efficiently, how to utilise the companies' technology and data to better shape the city, etc.

Since, this research only focuses on Beijing as the single case study, there might be other cases that could be studied and compared to reveal the differences in DBSS's contribution at a different city scale. Moreover, with the expansion of DBSS companies to other parts of the world, appropriate coordination between the local government and the private firms to avoid potential chaotic situations is required. By observing the Chinese experience presented in this research, further studies may focus on how to develop the DBSS in cities worldwide, as well as on researching the obstacles that the DBSS is facing and how to solve them in different contexts. DBSS and its healthy development and governance need more valuable investigation in future research.

Funding: This research received no external funding.

Acknowledgments: This research work is supported by Erasmus Mundus PLANET Europe program EPMC scholarship funded by the Education, Audiovisual & Culture Executive Agency (EACEA) of the Commission of the European Communities.

Conflicts of Interest: The authors declare no conflict of interest.

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