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Comparative Analysis of Sharing Bike Systems Based on Sustainability Indicators

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Abstract:
With the growing importance and widely application of the sharing bike system in public transportation systems in cities, many relevant problems emerged, which brought serious influence to the sustainable development of the system. The aim of this paper is first to research the existing sustainability indicators of urban mobility system through literature reviews, next it is to redefine and select the related indicators of sharing bike system through deeply understanding the evolution of bike sharing systems in cities from a sustainable point of view. Then, indicators are selected and applied to better understand the generations of sharing bike systems after the description of the different generations of sharing bike systems. The comparison highlights which characteristics of sharing bike system should be considered to adopt to a sustainable urban development and which features of the sharing bike system could need improvement and change to cater to active demand of the city development.

Keyword: sustainability, urban mobility, sharing bike system, indicators,

1. Introduction

Newly statistics forecast shows that urbanization is bound to become urban development trend in future world and the urban population will reach 66% of the world population (Ferreira, Walsh, and Ferreira 2018). With the development of urban transportation diversification, the movement of urban personnel constitutes a basic and important unit of urban activities, and the movement of personnel is inseparable from the means of transport in the city. Consequently, the enormous pressure of the traffic is increasing indefinitely and in the same time inhibiting the urban's development even if the cities have been devoting to develop sustainable public transportation (subway, tram, public bus…..) or to promote electrical cars. Therefore, the development of urban related to more health and virtuous circle style has been more than just considering subway, tram, public bus …, also some new way came up, such as sharing bike, which could help to improve urban transport mobility system. And the issue of sustainable development has always became the direction and benchmark for the urban development process. Now, there is no universally unified definition of sustainable urban development and sustainable mobility urban in the academic world. The definition of the target of sustainable mobility transportation is to insure the decisions of affecting transportation activity take into account the economic, social, and environmental consideration by Litman (Litman 2017).

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With increasing of private cars recent years, the negative effects of using cars have come to been realized, such as congestion, air pollution, noise pollution, safety, climate change and physical activity. These negative impacts had made people more interested in alternative mobility systems (E Fishman 2014; Handy, van Wee, and Kroesen 2014). More and more companies promote electric-mobility and the development of information and communication technologies (ICT) for urban transportation, as for example sharing systems with mobile phone applications (Opgenoord and Caplan 2017; Zmud et al. 2013). It is an affordable system that can benefit from the development of ICTs, especially in developing sharing bike systems. As the result, the advent of those technologies urban cycling represents a powerful system and is widely developed.
With the development of China's new generation sharing bike, the paper proposes to research a sustainability understanding of bike sharing system (SBS). The first section shows an in-depth study of the basic process of the evolution of the four generations SBS. The second section presents the identification of indicators expressing the impact factors. After a literature review research in the first two sections, in the third section, the research aimed to redefine the indicators from three dimensions as economic, environmental and social according to comparing the different generations SBS. A discussion is finally engaged to define the limits of the approach, and some perspectives are proposed for a more detailed research.

2. Bike Sharing Systems Introduction

Many academic articles provide an overview of the concept, history and future development of public bicycles (Shaheen, Guzman, and Zhang 2010). The advantages of the public bicycle system are generally summarized: a) strong flexibility; b) less emissions; c) savings in personal expenses; d) reduced congestion and energy consumption; e) good for health; f) conducive to "Last One Kilometer" which connected with multiple modes of transportation. However, not all urban developments can fully appreciate the advantages of these public bicycle systems.
According to relevant research (Elliot Fishman et al. 2014), since the total number of the global public bicycles growth had increased continuously, from nearly 50,000 in 2007 to 400,000 in 2012. However, the annual increment of public bicycles shows that the growth numbers had nearly reached a peak of 90,000 units since 2011, and this date had begun to show a slow downward trend from 2011. The continuous increase in the total number of public bicycles indicates that the advantages of shared bicycles have prompted many cities to vigorously develop shared bicycle systems in order to improve the efficiency of urban traffic movement. However, the decline trend in the annual growth indicates that the disadvantage of sharing bicycles has inhibited the deeper and more sustainable development of urban shared bicycles. From an historical point of view, public bicycles growth has undergone three evolutionary stages (Shaheen, Cohen, and Martin 2013; F Wu and Xue 2017) which could concludes below: free bikes; coin-deposit system; IT-based system. In 2014, the dockless definition of SBS appeared in Peking University campus and then popular in many cities of China after 2016. More and more researches (Kou and Cai 2018; Shen, Zhang, and Zhao 2018a; Shi et

al. 2018) focus on the dockless SBS which is the main character. The four generations of sharing bike systems are detailed below.

2.1 The first generation——free bikes

The public sharing bicycle could be traced back to the program "white bicycle" of Amsterdam in 1965. An anarchist organization painted some un-locked bicycles in white color which were placed randomly in some blocks of the urban for long-term free use. In the first generation system, there was no docking ports for parking, users were free to choose a parking spot optionally. At that time, there were no rules and regulations which stipulated about the area allowed to park public bicycles. Due to the un-locked bicycles that were painted in white color, the event was also named "free bicycle system" and "white bicycle system". However, the service was eventually stopped because of the thefts and sabotages of the bicycles provided. Only few basic small-scale associations were still operating. This attempt was recognized as the origin of the public bicycle system. (Corcoran et al. 2014; Shaheen, Guzman, and Zhang 2010; Shaheen, Mallery, and Kingsley 2012)

2.2 The second generation——coin-deposit system

In 1995, the second generation of public bicycle system appeared in Copenhagen with many improvements over the previous generation. Some bikes were specially designed for intense utilitarian with solid rubber tires and wheels with advertising plates, and could be picked up and returned at specific locations throughout the central city with a coin deposit. The fixed docking station were applied in this generation to prevent thefts. The anonymous user borrowed the bicycle with putting the coin as a deposit and get the coin returned after use. While although coin-deposit system conduced to reduce theft and vandalism, the problem is still not eliminated. (Shaheen, Guzman, and Zhang 2010)

2.3 The third generation——IT-based system

The problems experienced in the first-two generations promoted the development of the third generation. In 1997, the third generation of intelligent public bicycle system appeared in Rennes, France. This system is also named "IT-based system" which uses the intelligent card technology and the control panel to inquire the rental or return records and check the bicycle information at nearby station. User's responsibility has been improved through deposits and transaction records with the credit or debit cards. Moreover, the electronic and GPRS wireless communication systems of IT-based system insure to pick-up, drop-off, and tracking. At the same time, the government transfers the rights of the development and the advertising to companies with the profits of the companies come from advertising. IT-based system has established the operation mode of contemporary public bicycle system include for docking stations, kiosks, or user interface technology for check-in and check-out, and advanced technology (e.g., magnetic-stripe cards, smartcards, smart keys).

2.4 The fourth generation——dockless SBS

Fourth-generation sharing bike system is an evolving concept that has yet to be fully deployed especially in recent China. In 2014, students from Peking University created the OFO Company and initialize the fourth generation bike sharing system in campus. In 2016, a number of private competing app-based dockless bike-sharing programs have started to appear in numerous cities across China.(*Bloomberg.com*. 2016) The so-called fourth-generation sharing bike system was proposed on the basis of the third-generation through implementing improved technology of bicycle, such as a solar-powered light, smart lock, dynamo light, anti-theft pedal, solid rubber tire, electric hub and so on. Advanced mobile application technologies are also combined in the system, such as GPS search bicycle position, mobile smart payment system, and credit guarantee system. Infrastructures on road also has a large reduction, just like the dockless concept. The latest generation of SBS was completely profit-oriented by companies. Under the trend of profitability, there were 15 shared bike companies at the same time in the Chinese market(Lan et al. 2017; Shen, Zhang, and Zhao 2018b).

2.5 Evolution of sharing bike system (SBS)

The development of sharing bike system is a process of continuous improvement and technological innovation. Compared to the first generation, the second-generation was designed to reduce thefts and damages by adding a simple technology system (depositing coins). The third-generation has set up the docking station, kiosks, or user interface technology to facilitate the usage. While these technologies are also convenient for managers to track and obtain information of bicycles. The fourth-generation of SBS is more prominent than the previous generation SBS in terms of the technological upgrade. The latest system completely canceled the fixed docking station which directly reduces the investment costs for infrastructure construction and contribute to the sustainable development of SBS. In conjunction with the system's dockless design, the bicycles electronic lock function has also been upgraded, and the corresponding mobile phone application has been launched to match the bicycles that are parked at random, to complete the unlocking and locking behavior and the final payment. The other different evolution change is the mode of operation, such as the fully supports by local government and encourages for the customers to choose the sharing bicycles in the beginning of operate public bike model, so the promotion, service, and publicity of bicycles are all launched by governors from the first and second generation. To the third generation, partial funding was provided for the sharing bike industry. The companies are mainly responsible for publicity, operation and maintenance tasks with transforming the sharing bike industry into a profitable operation business model. Finally, the ultimate goal of the fourth generation is profitability without government funding.

3. Sustainability Indicators Of Urban Mobility

3.1 Literature reviews of urban mobility system

Urban mobility is one of the fundamental aspect to understand the sustainable development of cities. Urban mobility system exists in the basic natural environmental which cannot be ignored any behavior activities have an impact on

the air, water, noise and energy change. Researchers always tried to define indicators to express mobility from economy point of view. Urban mobility must have some kind of relationship with people, so it will definitely bring social impact about indicators, such as the safety problem, satisfaction level, equity problem, and some other social impact. The comprehensive analysis was taken account by Gudmundsson through determining the limits of the environment, distributing the economics of the different sectors and isolating the transport to society problem (Gudmundsson 2003). The indicators need directly or indirectly reflect the sustainability and harmony of the transportation system. They are not dedicated to a specific transportation mean, they give a global point of view, like those proposed in the statistical measures of social, environmental, and economic sustainability by Organization for Economic Cooperation and Development Countries (OECD) (Haghshenas and Vaziri 2012). Other researchers focus on indicators that mix technological and human considerations, such as "fossil fuel consumption", "number of vehicles", "length of motorway system" and "human development" as the primary indicator to evaluate the capabilities of the Hungarian road transport sector (Szendrő, Csete, and Török 2014). Other aspects can be considered, such as accessibility, congestion, or co-benefits (Buzási and Csete 2015a). Some indicators collected from Hungarian Central Statistical Office (KSH, http://www.ksh.hu), in the research report of Hungarian, there are 23 economic indicators, 14 environmental indicators and 7 social indicators. Monzón(Monzón, Fernandez, and Jorda 2009), mainly identified the indicators regarding environmental and social costs of different transport modes in Madrid. They quantified the cost of transport modes through comparing and analysis the infrastructures, operating costs, travel time, economic costs, accidents, noise, air pollution, land taken. In this article, Jain and Tiwari (Jain and Tiwari 2017) implement a new approach of selecting sustainable mobility indicators for Indian cities through comparison and combining of three indicators selection framework about the criteria based, causal chains and causal network.

3.2 The impact factors of urban mobility system

Towards the principle of created indicators, the first step, it is highly important to make the boundaries of the city. Secondly, the evaluation system need to be separated, such as the distinction between urban transportation from larger transportation systems, the person- transport system or a specific transportation system. The third step concerns the identification of used indicators with the approaches in the international studies (Zegras 2006). These steps depend on the purpose and objective because of the different urban status. Santos think that it is a way to simplify the complex issue of sustainability in order to using indicators effectively (Souza Santos, Kahn Ribeiro, and Souza 2013). Litman suggest that a complex indicator system is more effective to evaluate the target than using a set of single indicators (Institute and 2009 2010). Hence there are different approaches to collect and definite indicators because there is no agreement on the definition of sustainable urban transport. There are no internationally accepted standards for collecting, evaluating and regulating indicators, however, the indicators have three main function: simplification, quantification and communication (Toth-Szabo, 2012).
After consolidating relevant indicators which related to some projects and urban mobility policy of different cities from the literature of urban mobility system. Nearly the

151 assessment indicators of sustainability in urban mobility were roughly grouped according to 3 dimensions: economic, environmental, and social. Secondly, determining the scope of the research for the first screening: clearly the sharing bike system (SBS) is the object of research in urban mobile systems. According to the whole urban mobility system in the first step, the indicators had been collected, while some indicators which don't have inconclusive relationship with SBS should be filtered out, such as some projects considering the indicators of mobility with particular emphasis in freight transport (Buzási and Csete 2015b). The relationship between freight transport and public bicycle transport still needs to be verified, so the relevant indicators of freight transport are not selected as indicators for evaluating the SBS. Thirdly, the impacts of the SBS is considered for a deeper understanding of the choice of indicators. A comprehensive indicator set should reflect various goal and a sustainable SBS indicator set should reflect the impacts of sustainable transportation (Litman 2017). For example, a comprehensive sustainable transportation indicators need reflect the impact listed in Table 1. Analyzing the existing indicators of urban mobility indicators, 10 impact factors (Table 1) are summarized according to Litman who defined the impact factors in terms of objectives, goals, targets and threshold (Litman 2017). The research identify the new factors involved in SBS according to three based principles: first, the indicators system to be analyzed and
evaluated should relate to the existing urban mobility indicators. Second, the impact factors are divided into specific functional areas of urban mobility system (such as public transportation, public infrastructure, urban land), related policy areas (such as policy costs), affected group (such as travelers, managers and disadvantage people), and natural resources (such as air, water, energy). Finally, statistical literatures using the number of relevant indicators in order to screen and analyze relevant SBS indicators in following research.

Table 1. Number of factors in reviewed literature grouped

Reference	**Sustainable transportation impacts**									
	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10
(Jain and Tiwari 2017)	4	2	2	2	5	3	2	4	1	1
(Buzási and Csete 2015b)	4	3	0	4	1	2	12	6	0	0
(Haghshenas and Vaziri 2012)	2	1	1	1	1	1	1	1	0	1
(Szendrő, Csete, and Török 2014)	1	1	0	0	0	0	1	0	0	1
(Litman 2017)	6	2	1	1	3	1	4	3	2	3
(Miranda and Rodrigues da Silva 2012)	5	9	2	3	2	2	4	2	0	0
(Macedo, Rodrigues, and Tavares 2017)	6	2	1	0	1	2	1	1	1	0
(De Oliveira Cavalcanti et al. 2017)	3	6	0	0	0	0	1	0	0	0

NOTE : F1:Public transportation and other transportation; F2:Public infrastructure; F3:Urban land; F4;Travel related factor(traffic models); F5:Urban development security; F6:Related policies and policy costs; F7:Travelers or operation; F8:Air, noise and water pollution; F9:Disadvantaged group; F10:Energy consumption

4. Selection Of Indicators For Shared Bicycle

According to the research of the sustainable mobility above, many mobility indicators have been established in the entire urban mobile system including public transportation, private transportation, sharing traffic and so on. Most previous researches presents a trend that the larger system, the greater the number of indicators selected. With the constant update and upgrade between different generations of sharing bike system, and the active promotion of local cities. The development of SBS is a double-edged sword. Discovered favorable indicators could give affirmation and continue to carry forward, and identify unfavorable indicators need improve. Not all of the indicators for sustainable mobility indicators can be applied to sharing bike system, and these are many overlap indicators to describe the same events through different definitions. Therefore the re-screened indicator system need to be analyzed according to the impact factors that are roughly divided into 10 modules. Then, description of the indicators is given which have the relationship with SBS in the urban sustainability system. We should re- edit and redefined by correlation analysis between the above literatures indicators and cities' SBS characteristic to find effective indicators which can be applied between different generations SBS. As in previous research the characteristic of sustainable transportation was measure from the environmental, economic and social aspects. The indicators of SBS also is redefined around three dimensions ------social, economic, and environmental. The following research demonstrate the principle of selecting indicators, then these selected and redefined indicators are compared in different generations SBS depending on whether it is directly or indirectly related to different generation SBS. The new indicators system involved in SBS are shown in the Table 2. In the table, the "X" means the corresponding generation of SBS is qualified to this directly or indirectly indicator. All the judgement is made by the researchers according to the literature research and an adequate understanding of each SBS generations.

Table 2. Contrast sharing bike system part of indicators

List of indicator		SBS 1	SBS 2	SBS 3	SBS 4
Social	Per capital SBS expenditure versus per capital public transportation (including vehicles and			X	X
	Public services within 10 min walking distance to				X
	sharing bike stop				
	Travelled kms by sharing bike	X	X	X	X
	Public versus private transport				
	Motorized versus non-motorized modes				
	Percentage of SBS in traffic interchange			X	X
	Percentage of journeys by bike	X	X	X	X
	Pavement condition index of bicycle paths		X	X	X
	Proportion of cycle ways in road route		X	X	X

	Proportion of streets with sidewalk		X	X	X
	Length of the cycle ways		X	X	X
	Parking area of SBS station (Occupancy rate of parking station)		X	X	X
	Travel time spent in bike	X	X	X	X
	Average trip distance once riding bike	X	X	X	X
	NO. of average daily using bike	X	X	X	X
	Bicycle occupancy rate	X	X	X	X
	Proportion of crashes and fatalities relation to bicycle	X	X	X	X
	Actions to improve user safety		X	X	X
	Relevant policies about safety				
	No. of employees			X	X
	Average age of passenger bicycle	X	X	X	X
	Portion of residents who riding bicycle for travail and health	X	X	X	X
	Accessibility for disadvantage group				
	Quality of transport for disadvantage people (disable, low incomes, children etc.)				X
	Universal accessibility design				
Economical	The local government expenditures on SBS	X	X	X	
	Value investment			X	X
	Average wages of employees in company			X	X
	Income level of the sharing bike passenger	X	X	X	X
	Costs of individual/ public transport per capita			X	X
	Costs of SBS in % of total transport costs			X	X
	Investment cost of parking construction		X	X	
Environmental	Proportion exposed to air pollution				
	Proportion exposed to noise levels > 50db				
	Per capita air pollution emissions (various types)				
	Energy consumption by fuel type per capita				

4.1 Economic

Most of the indicators for the economy come from the impact factors on public infrastructure (F2), related policies and policy costs (F6) and travelers and operation (F7). If the public transportation mode is the filling of the urban mobile system, the infrastructure of public transportation are the important supporting skeletons in the urban mobility system. The infrastructure of the urban mobile system is also the mainly element infrastructure of SBS, which mainly reflected in the road and parking construction that are compatible with the traffic modes (e.g. kiosks, dock piles…). According to understanding the different generation SBS(Section 3), from the less consideration of fixed parking station in first generation, to the establishing of fixed station in order to regulate the management in generation two, then the cancelation of the setting of the fixed station for the new generation now.

The operators of the first and second generation SBS are government who are not for profitable operation. The third generation SBS is enterprise-led and government-supported. The fourth generation SBS is fully operational for profit-oriented. The important factor of the operator and government cannot be ignored due to the role of company and government. Manager's behavioral activities and results show management efficiency, such as value of investment at current prices, net sales value and employee average wages (Buzási, 2015), accessibility to essential services, expertise or training of technicians and managers (Miranda and Rodrigues da Silva, 2012). As the company needs to hire a large number of employees who could efficiently coordinate to finish the key tasks such as supervision, maintenance and other services, so value investment, employees' average wages (Buzási and Csete 2015b) can be used as an important indicator to evaluate company efficiency. For the company, the most basic maintenance costs of SBS refer to repairing broken bicycles and customer service maintenance for service customers. when Wang (Wang and Chen 2017) investigated the service quality of SBS, he classified maintenance service as database system maintenance (DSM), billing system maintenance (BSM) and customer service maintenance (CSM). With the second generation SBS beginning to set the fixed docks, the maintenance cost also beginning to increase the infrastructure maintenance cost and management cost. With the third generation BSB upgraded intelligent IT system, the DSM for collecting and managing customer data has been added, and the BSM has been completed through smart cards. The technology innovation of dockless system is the combination of mobile phone application to locate bicycles, unlock and lock, and payment system, so it increased the mobile application system maintenance (MASM) costs.

The traveler's concept of consumption in mobility transportation is important factors. Combined with the correlation analysis of SBS, the consumption concept of sharing bike users also directly affects the sustainable development of SBS, the indicator of Costs of individual/public transport per capita reflects the user's attitude towards sustainable urban transport, and the indicator of Costs of SBS in % of total transport costs highlights the division of the proportion of sharing bike in the user's mind. It should be noted that the total transport costs refer to short-distance traffic because the shared bicycles mainly accomplish short- distance travel behavior. These indicators related to consumer spending also fully reflect the criteria of affordability.

4.2 Environmental

Most of the indicators for the environmental come from the impact factors on air, noise, and water pollution (F8) and energy consumption (F10). Any development cannot be separated from the environment of human life. Similarly, the development of urban mobility systems is inseparable from the basic environmental elements of the city: air, water and noise. The urban pollution indicators mentioned in papers (Jain and Tiwari, 2017; Buzási, 2015; Haghshenas and Vaziri, 2012; Litman, 2017; Miranda, 2012; Macedo, 2017) mainly come from the emissions of GHG, COX, NOX, PM2.5 and other gases, the discharge of water pollution and the impact of noise related to the entire urban mobility system including SBS. Therefore, the ratio exposed to air pollution, the proportion exposed to noise levels > 50db and per capita air pollution emissions (various types) can indicate the relationship between SBS and the environment. Energy

consumption is another important indicator of the environment in urban mobility systems which relates to the use of vehicles, such as per capita energy consumption by fuel type (Jain and Tiwari, 2017), use of renewable fuels and impacts on special habitats and environmental resources heat island effects (Buzási, 2015), and transport energy use per capita (Haghshenas and Vaziri, 2012). Sharing bike as an important part of the urban public transport system, the indicator of energy consumption by fuel type per capita is an important indicator for verifying energy consumption of bicycle. During customers' use the bike to complete the travel, the biggest contribution of generalization and application to the environment is that they don't consume the fossil fuels and electricity, so there is no harmful gases are emitted. That is why people call public bicycles is the green traffic.

4.3 Social

The impact factors divide the most of the indicators about social dimension. Travel efficiency is also related to the personal factors of the traveler (Buzási, 2015) that the age and cognition of the traveler. Murphy (Murphy and Usher 2015) turn to the profile of the respondents by age, the results show that the majority of respondents (58.8%) are between the ages of 25-36, with 22.6% falling into the 37-48 old and only 4.8% in more 48 old. So the average age of passenger bicycle is a necessary indicator to be considered in SBS. And the age of the user is relative younger for the new generation SBS because of the advanced technology. The sharing bike has a prominent and special function is to meet the purpose of travel or exercise for the user, the indicator of portion of residents who riding bicycle for travail and health (Litman, 2017) should be an important indicator of SBS.

The travel time which is an important indicator of the transportation system are mentioned in the research of transportation methods regardless of the article on sustainability indicators or the articles on sharing bike system (Elliot Fishman, Washington, and Haworth 2013; Frade and Ribeiro 2015; Wang and Chen 2017). The less time on travel time reflects the more effective sustainable system, while also improving the system service level. For the SBS, travel time is to complete a set of mobility activities which starting from an origin point to the public station (rent bicycles), then riding the bicycle to the other station (return bicycles), finally to the final destination. Travel time is limited by the user's physical strength. The longest riding distance that the user can tolerate each time (Sharing bicycle industry status report 2017), shows that 61.3% of users are riding less than 3000m each time, with 30.7% between 3000m to 5000m, and only 8% of users exceed 5000m. At the same time, travel time is also limited by length of cycle way path and the condition of parking public bike. The comfort of the user are directly related to the road conditions and cycling environmental for SBS, relevant indicators such as streets with sidewalk (Jain and Tiwari, 2017) should been considered to reflect the important idea in SBS: sharing bike should be in harmony with pedestrian. So proportion of streets with sidewalk should be defined as one of indicator. So proportion of streets with sidewalk is defined as one of indicator.

Elliot Fishman (Elliot Fishman, Washington, and Haworth 2013) summarized the daily usage rate in different countries which the maximum usage rate is 7.9% in Barcelona, and the minimum usage rate is less than 1% in Brisbane. The latest generation SBS

complete the basic steps of using sharing bike through the mobile phone, the activity survey data of the users who use the mobile APP (Sharing bicycle industry status report 2017) showed the average number of active users per day in January 2017 was 98.9 million. The number of users in SBS can indirectly reflected the customer's interesting for using sharing bicycles. With the widespread use of third-generation shared bicycle systems, the number of shared bicycles has increased dramatically according to statistics of the Bike-Sharing World Map (Meddin R n.d.), which reached nearly 50,000 in 2007, and to more 6,000,000 bicycles in 2012. The market has become saturated and suffered tremendous pressure on management of urban traffic. Therefore, researching the percentage of journeys by bike can understand the characteristic of journeys, and then guiding the manager to allocate the number of sharing bicycle.

Safety is the most direct factor that reflects the quality of urban mobile system. Security mainly involves the safety of passengers or residents who exist in urban mobile systems and is represented by per capita traffic crashes and fatalities (Jain and Tiwari, 2017; Haghshenas and Vaziri, 2012; Litman, 2017). Actions to improve user safety (Macedo, Rodrigues, and Tavares 2017) was an indicator for positively evaluating the safety of urban systems which was reflected in the detailed activities of urban mobility activities. For SBS, there are also activities that improve the user's safety, such as bicycle lights and the obvious bicycle Silverlight coating for users in the dark. And putting forward relevant policies also, such as the use of protective equipment such as helmets, protective clothing etc. or whether the user need obtain the relevant bicycle license before entering the road.

Vulnerable groups such as children, the elderly and the disabled are also important groups that cannot be ignored in the urban mobile system. The indicators of accessibility for disadvantage group by different modes (Jain and Tiwari, 2017), quality of transport for disadvantage people (disable, low incomes, children etc.) (Litman, 2017), all fully express the concern for the vulnerable groups. For SBS, paying attention to bicycle parking should not affect the use of the Blind lanes, and taking into account the rules of the use of public bike who settings, such as restrictions on the use of the bicycle's age. Meanwhile, for the consideration of persons with disabilities, by changing the design of the bicycle in order to apply to more extensive groups.

5. Discussion and perspective

As the role of the SBS in the entire mobility system becoming more and more indispensable and most previous researches on sustainability indicators were conducted from a macro perspective and focused on the entire urban mobility system which included public transport, cars, rail transit, bicycles and even walking. The in-depth study of sharing bike system on the sustainable urban development is very much urgent with the rising status of sharing bike development with the trend of sustainable urban development.

The sharing bike system could be divided into four generation according to the basic characteristics which were investigated from the sustainable perspective after a research the evolution process of sharing bicycle in depth. The newly fourth generation SBS (Dockless SBS) was proposed to help compare the basic features of different generation

SBS. Compared with the three earlier generations, the fourth generation (also known as the dockless public bicycle system) has brought users much more convenience and help to make the whole system smaller and more sustainable.

Most of urban sustainability assessment methodologies depict a focus in three of the sustainability dimensions: economic, social, environmental. The initial work is to find the evaluation indicators applicable to the SBS from the dimensions of these three aspects through summarizing the basic operation characteristics of the SBS and the feedback information of each survey data. Obviously, this result is not comprehensive, because the pollution of the sharing bicycle to the environment have no side effects compared to the wasted tail gas produced by other vehicle with consuming non-renewable energy resource. In the market service stage, the sharing bicycle driven by green energy have its natural advantages with taking into account the production stage and recycle stage of shared bicycles. Therefore, the indicators introduced only in the light of basic service characteristics of bicycles between different generations are only applicable to one specific life cycle stage or a certain group experience.

The method of selecting the evaluation indicators is suitable for SBS through the review literature and comparison methodologies between different generations sharing bike has limitations, because it cannot cover all the indicators of the entire sharing bike system.

6. Conclusion

As the sharing bike system is becoming a non-negligible part of the urban sustainable mobility system, it is extremely urgent to establish an evaluation indicators for the sharing bike system.

An extensive literature review on SBS was conducted on a sustainable development perspective. The basic process of the evolution of the four generations SBS was investigated in-depth and the identification of indicators expressing the impact factors and evaluating sustainability of systems were presented.

From the set of existing urban sustainability assessment indicators, a group of sustainability indicators which is suitable for the SBS was selected in the view of sustainable development by describing the information of SBS and contrasting the data of different generations of sharing bicycles. Obviously, it is difficult to compare different indicators between different generations, because of several reasons, such as social categories, the obtained index data cannot be compared horizontally under different social backgrounds. Therefore, it is necessary to establish a new theoretical model to process for comparison, the future research needs to expand the process of creating indicators that cover the entire life cycle system, and finally get more suited indicators based on the entire life cycle.

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