The Relationship Between Bike Sharing and Carbon Emissions

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Abstract: Bike sharing always been regarded as one of green transportation to reduce carbon emissions all over the world. It was a sustainable development method supported by governments. While the emergence of bike sharing provides convenient transportation for humans, the current situation of bike sharing is facing several challenges in our cities. Intensive carbon emissions might be produced from continuous production of sharing bikes under the oversupply problem which has a negative effect on the urban environment. This literature review proposed to reconsider the relationship between bike sharing system and carbon emissions to recognize the real meaning of bike sharing. The article overviews the development of bike sharing system, summarize from the history of bike sharing and design the measurement of bike sharing system with study cases in recent years. Collecting carbon emissions computational formula calculates life cycle carbon dioxide emissions of bike sharing to evaluate energy consumption. However, some studies remain narrow in focus dealing with the design method of bike sharing system or carbon emissions estimate. These findings signal the need for additional studies to investigate more about the adverse impact of bike sharing and try to keep the balance supply with demand to protect our cities' environment.

Keywords: Bike Sharing System; Carbon Emissions; Life Cycle; Imbalance

1. Introduction

Carbon dioxide plays an important role in the ecosystem. In recent years, human activities exacerbate carbon emission led to the issue of global warming increasingly serious. The global concern started to focus on carbon dioxide which is impacted by man-made. With the development of cities, people try to reduce the carbon emission in urban to protect our environment. DeMaio suggests that we can reduce traffic activities to protect the surroundings by increasing the use of bike sharing[1]. The appearance of bike sharing has enriched people's transportation forms, bringing convenient services for the public at the same time. According to a recent article pointed out that bike sharing can remit the pressure of traffic jams with low prices to use in our daily life and promote a substantial economy in some countries. However, the article also mentioned some problems in bike sharing, such as location management or destruction of the environment, etc[2].

With the development of bike sharing systems increasingly, it become a vital part of public transportation in urban planning. Nevertheless, we find that there is barely an essay collecting global bike sharing system data after doing the research. We can understand the bike sharing density and distribution from world map (Figure 1) in some regions, it is hard to assess the whole bike sharing system from a global perspective because of lacking data. There is a fraction of relative data exists in part countries only. Figure 2 displays a comprehensive knowledge map in bike sharing field from 2010 to 2018[3]. The embranchment which is named 'Main Regions and Institutions' also highlights the main regions in bike sharing system around the world, like China, the USA, Canada, England, and Australia.

The aim of this work is to discuss the relationship between carbon emission and bike sharing systems in some places which have bike sharing systems. The article is divided into several parts to discuss. First of all, it is worth considering the

history of bike sharing system. Secondly, the essay compares different management methods combined with case studies. Moreover, it is significant to estimate carbon emissions through analyzing previous works to understand green travel of bike sharing. The references mainly focus on improving bike sharing systems and calculation data of carbon emission. But the most likely need to be solved that recognize the influence of the oversupply bike sharing issue to balance with carbon emission in the future.

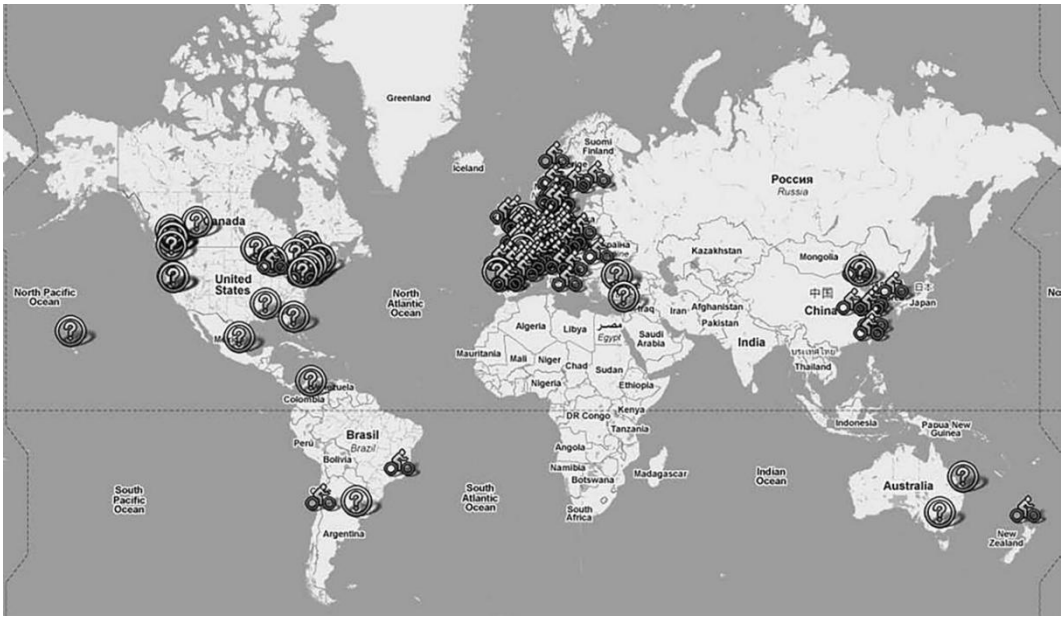


Figure 1. Bike Sharing World Map [4].

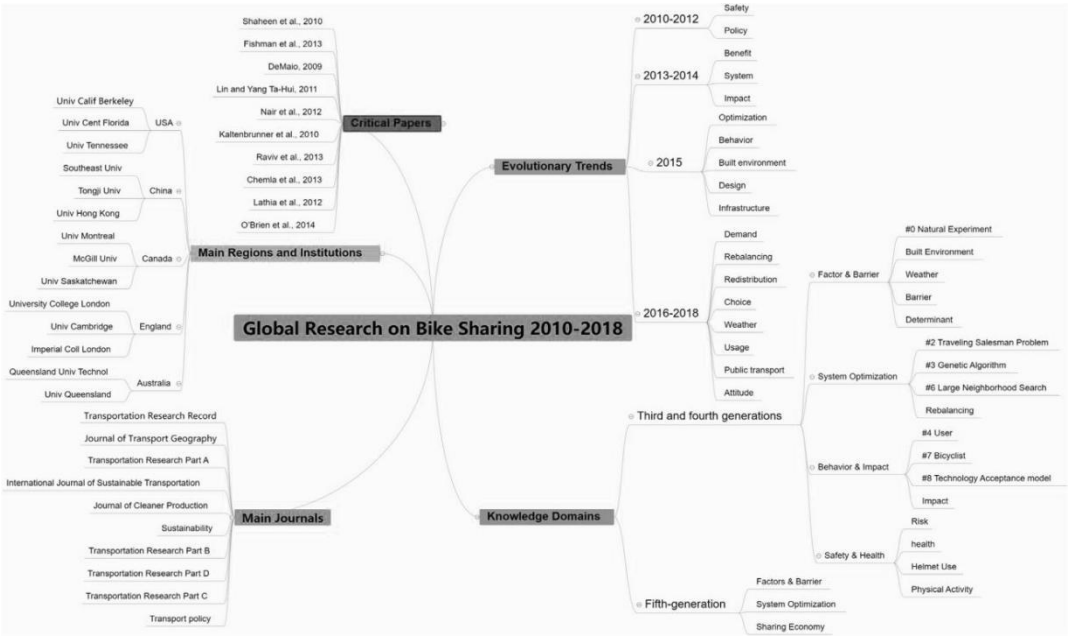
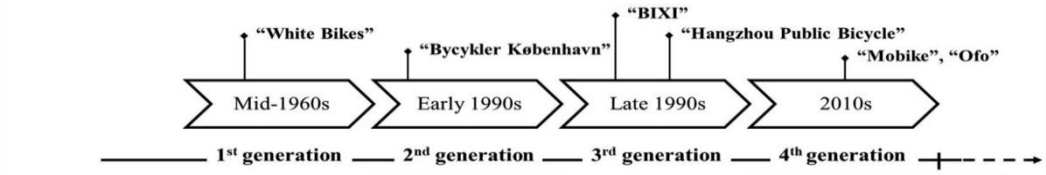


Figure 2. Global research on bike sharing：2010-2018[3].

2. The History And Impact of Bike Sharing

Bike sharing develops for decades. Figure 3 shows the generations of bike sharing clearly. Demaio concludes that bike sharing has been updated three times in the past forty-five years[1]. The first (Free Bikes) and second-generation

(Coin-deposit system) were published in 1965 and 1991 respectively. Although bike sharing programs were continuously improving during this period, bike sharing was still being stolen for private use in the end. The third generation (Docked IT-based system） of bike sharing program was held at a university in 1996. The technology of bike sharing was improved and combine with electric devices, for example, on-board computers and so on. Then, the development of bike sharing became slow in the next few years. Until 2005, the third-generation bike sharing program has an apparent effect with 1500 bike sharing in Lyon. After that, the development of bike sharing seems to be on track. The program of bike sharing was widespread in other countries except for Europe at the end of 2008, like China, the United States, Brazil etc[1].



	Free bikes	Coin-deposit system	Docked IT-based system	Dockless IT-based system
Components	• Bicycles	• Bicycles • Docking stations	• Bicycles • Docking stations • Key/cards connected to payment • Mobile application	• Bicycles • Mobile application
Characteristics	• Free of charge • Users anonymous • Bicycles unlocked • Bicycles located at arbitrary places in a certain region	• Free of charge • Users anonymous • Bicycles locked in specific docking station • Coin as deposit used to unlock bicycles; deposit coin retrieved by returning bicycles to stations	• Usually paid as a membership service, or used temporarily • Users verified with real identity • Bicycles locked in specific docking station • Technology (smartcards, or user interface kiosks) used for picking up and dropping off bicycles in stations	• Pay a deposit for being a member (recently some operators have cancelled the deposit) • User verified with real identity • Charge based on usage time on mobile app or seasonal subscription • Bicycles locked • Bicycles located at arbitrary places • Smart locks, bicycle searching, locking and unlocking via specific mobile app
Cities	1-10	1-10	Over 1000	Over 200
Development paths	Originated in Amsterdam, the Netherlands	Originated in Copenhagen, Denmark, later expended to Europe	Originated in Portsmouth, UK, later expended across the world	First large scale implemented in Beijing, China, later expended to Asia, Europe and the Americas
Main financial resource	Public investment	Public investment	Public investment	Venture capital funding
Collaboration with public transit agency	NA	NA	• Through payment • Clustering the docks around public transport stations	Not yet

Figure 3. Bike-sharing system generations[5].

The impact of bike sharing is complex. Some researchers propose that it is important to notice the advantage and disadvantages of bike sharing from the perspective of environmental benefits[6]. On the one hand, bike sharing improved connectivity with others transportation to reduce traffic jams and inspired more people to ride bikes which can keep health in their normal life[1]. On the other hand, it might cause supply imbalance problems. Each country has various impacts on economic growth patterns when bike sharing programs enter. The different countries had various reactions. Here is a comparison between China and Ireland. The progress of bike sharing accelerates the sharing economy in China. Campbell states that bike sharing became more popular. Citizens can find colorful bike sharing utilizing their smartphones and around sixty companies have already put sixteen to eighteen million bikes sharing on the street within one year[7]. However, due to venture capital funding supporting dockless bike sharing, private businesses can avoid lengthy government approval processes with rapid promotion[8]. These companies did not consider controlling the number of sharing bikes due to fierce competition in the market. Some companies shut down to operation. For instance, Bluegogo went broke which has 20 million users and 700 sounds bikes[7]. Part of sharing bikes descend to negative effects during this process.

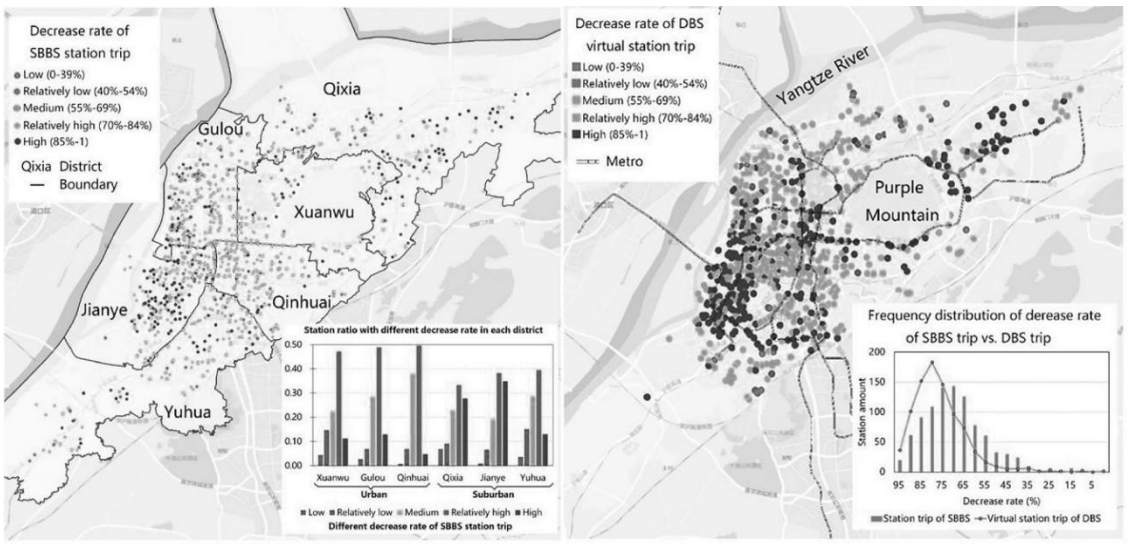
The report claims that the short-lived booming sharing bikes will be produced extra carbon emissions and waste a lot of materials during sharing bikes production[9]. By contrast, due to the advance of competitiveness and rise in output, bike sharing brings more advantages for Ireland under different development backgrounds and got more competitive than other cities[10]. Bike sharing systems are facing the challenge of environmental issues due to booming bikes in cities currently.

3. Management of Bike Sharing System

Chang, Song, He, and Qiu mentions that the deregulated nature of bike sharing system has led to a tremendous number of user parking violations, for example, hindering the flows of metro users or violating pedestrian rights[11]. Bike sharing systems need to reinforce to deal with the questions in urban transportation. There are two types of bikes sharing systems existing which need to be managed in our cities immediately, they are dockless bike sharing systems and traditional station-based bike sharing systems respectively.

Waston and Telenko contribute an application method that can help designers estimate users' preference demand for distributed appropriate traditional station-based[12]. The case study was in Chicago to analyze bike sharing station expansion data by algorithmic approaches and traces the development of bike sharing stations in Chicago to get precise results based on the previously existing data. Meanwhile, this approach has disadvantages. It relies on users' preferences too much. Users might change their mind to ride or not all the time but the stations are stable. Furthermore, the data record is not the newest one with the case study. Our urban construction might change already by increasing with more traditional station-based or not that it will influence the result accuracy.

As for the dockless bike sharing system, Others highlight the need to recognize the link between bike sharing system and carbon emissions and choose Xiamen, China as an example to optimize bike sharing system from the life cycle[13]. It proposes a framework to obtain the optimal solution of bike sharing with a simulation model, an optimization model, and a life cycle assessment model to control the number of bike production. This algorithm approach advantage is that can increase the bike utilization rates by decreasing bike sharing fleet size. But he measurement has a specific time around 24 hours only, it cannot observe for a period because of lacking data. At the same time, the demand of users might be change with other reasons such as weather, holidays, natural hazards, and so on[13]. Other research also found that the using time of bike sharing will shift seasonably[14].



(a) The decrease rate of trips in SBBS stations. (b) The decrease rate of trips in DBS virtual stations

Figure 4. The decrease rate of bike sharing system[15].

Coronavirus disease 2019 (COVID-19) has triggered a global pandemic, the transportation plays a role key in the spread of coronaviruses[15]. Citizens are limited to go public space and start to work from home, so the usage of public transportation declined during this period. Figure 4 draws on an extensive range of bike sharing data in Nanjing, China to access the decreased rate of bike sharing in a different system with the pandemic background. The article also mention that 'the dockless bike sharing fell by 82%, which is larger than traditional station-based (72%)'[15]. Overall, the management of bike sharing system could design from users, stations, and bikes perspective, it will better to set bike sharing system database and combine with social environment to the aim of sustainable development.

4. Calculation of Carbon Emissions

Although Pucher and Buehler argue that bike sharing is the most sustainable in diverse transportation methods, we should enhance the life cycle assessment of bike sharing to reduce the problem of extra carbon emissions[16]. In addition, Bonilla Alicea states that environmental sustainability might be damaged by adding produced electric devices compared with different types of bikes sharing[17]. Therefore, it is necessary to analyze bike sharing production which caused carbon emissions under technological updating. The disadvantage of bike sharing should not be ignored.

4.1 Life Cycle of Bike Sharing

According to the cycle process of bike sharing, Chen and Chen suggest that the whole life cycle of bike sharing is divided into three periods, they are production, use, and recycling disposal of respectively[2]. Every bike sharing needs to expend energy in the production and recycling period. By using a fixed calculation formula to calculate how many carbon emissions are generated in each stage. We need to analyze and figure carbon emissions from the component of bike sharing. Otherwise, it might change the meaning of bike sharing as a green way to travel in our cities. And point out carbon accounting method for production operation and maintenance stage, disposal stage respectively[2]. Based on BSI Group offers the standards to evaluate international greenhouse gas emissions in the life cycle[18], calculate formulas is as following[2]:

$$PPE = \sum_{k=1}^{n} (EC_k \cdot EF_k)$$

As the researchers note "PPE is productive process emission which used to count carbon emissions, while EC represents the energy consumption of producing bikes, and EF is the carbon emission factor of producing bikes". It is worth noticing that Chen provides an in-depth analysis of the equation in the operation and dispatch stage to get exact results[9].

During the disposal stage, calculate formulas classify carbon emissions as repeatable recycling and non-reusable portion which be regarded as solid waste incineration. Chen and Chen mention that the carbon emission of one sharing bike in the whole life cycle is 76 kg[2]. The highest proportion in the production stage of carbon emission was 87% and the energy consumption ratio of raw materials account for 93%. The raw materials production process is the main part of energy consumption[9]. Figure 5 illustrate that solar panel, steel components, and bicycle frame components occupy more than 95% of the whole life production process which affect our environment[17]. If we can reduce carbon emissions by promoting technology from raw materials production perspective, it might improve the advantage of bike sharing in sustainable development.

	Private bicycle		Smart bicycle BSS**		Smart dock BSS**	
Component	kg CO_2	% of total	kg CO_2	% of total	kg CO_2	% of total
Circuit board	–	–	545.70	37.40%	0.32	0.10%
Solar panel	–	–	573.90	39.30%	139.40	29.10%
Bicycle frame	70.72	78.80%	175.70	12.00%	175.70	36.70%
Alloyed steel	6.04	6.70%	147.80	10.10%	147.80	30.90%
Total	76.80	85.50%	1,460.00	98.80%	478.60	96.80%
	Private bicycle		Smart bicycle BSS**		Smart dock BSS**	
Component	Pts	% of total	Pts	% of total	Pts	% of total
Circuit board	–	–	50.40	34.10%	3.82	6.97%
Solar panel	–	–	54.60	36.90%	8.51	15.55%
Bicycle frame	8.24	69.08%	19.10	12.90%	19.10	34.90%
Alloyed steel	1.51	12.65%	21.63	14.60%	21.63	39.50%
Total	9.75	81.73%	145.70	98.50%	53.10	96.90%

Figure 5. Component carbon emissions in production process[17].

Conclusion

This article reviews the bike sharing history to bike sharing system management, it mainly focuses on investigating the opposite forces of bike sharing to discuss what can we do in reality and try to find a way to break this dilemma in countries which have a great number of bike sharing. The management of bike sharing system should base on the current situation. There has been a certain amount of research in this direction on methods to test carbon emissions. Nevertheless, researchers lack statistical data on the number of bikes sharing systems in many regions which has not led to precise results. Previous works point out how does recycling system deal with the disposal of bike sharing rarely. It also needs to be considered if it will increase extra carbon emissions. Future research could consider addressing the important issue of how to deal with oversupply in the number of bicycles promptly in order to balance the relationship with carbon emissions in cities.

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