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# THE INNOVATION OF DIGITAL DOCKLESS BIKE-SHARING FOR CITY'S AIR QUALITY AS SUSTAINABLE TRANSPORTATION

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**Abstract**

In China, air pollution levels have increased over the last two decades and are now among the highest in the world; one of the reasons is that of transportation. The purpose of this study is to investigate and analyze the innovation of digital dockless bike-sharing (DBS) in China to improve the city's air quality as sustainable transportation from the consumers' perspective. A comprehensive and exhaustive search of the literature on this industry, questionnaire, and interview were conducted. The obtained number of sample is 203 people. The method used a likert scale, and based on the ease (convenience sampling). This research focuses on the impact of DBS as a sustainable transportation for environmental, social, and economic dimension. The result shows bike-sharing represents a good example of green consumption in travel, and an innovative solution to meeting the needs of people to be mobile in the urban environment of the future. The respondents are aware that some environmental issues are caused by human activities, and they are willing to ride a dockless bike to help improve city's air quality.

Keywords: Air quality, DBS, Dockless bike-sharing, Innovation, Sustainable transportation.

## 1. Introduction

Technology is used to make better life for human beings. Technology is used for billions of people. However, it has produced unfortunate side effects; environmental crisis, transportation issues and has decreased air quality [1]. Among the many environmental challenges in cities, air quality is a major issue, which is particularly difficult to manage; from the factory smoke of industrializing cities, to the combustion of fossil fuels such as motor vehicles [2, 3]. Governments around the world have continuously struggled to reduce curb pollutants and emissions in the air.

Recently, air pollution levels in China have increased and are now among the highest in the world. Further, air pollution in outdoor makes deaths of more than 1.5 million people per year. Or, it can be approximated more than 4,000 people per day has been irradiated [4]. Three-eighth of the Chinese breathes "unhealthy" air (Fig. 1) [5]. The most dangerous pollutants are airborne particles less than 2,500 nm in diameter, which cause a number of health problems, including stroke, asthma, heart attacks and lung cancer [6]. Transportation is also another major source of air pollution in China at the national and provincial levels [7]. The use of a bicycle might be one of the solutions that could be helpful to many urban transportation issues [8, 9]. Figure 1 shows the capture of air pollution monitoring condition.

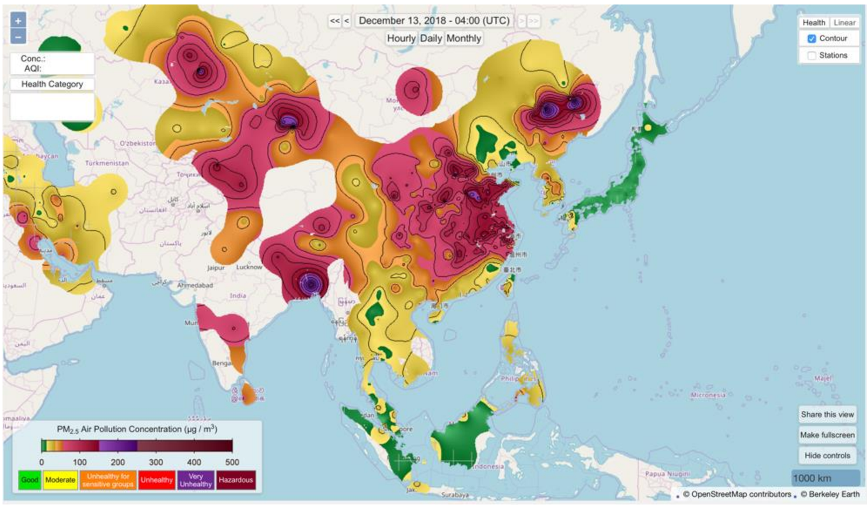


**Fig. 1. Map of real-time air pollution monitoring stations. The map shows the locations of air quality monitoring sites in China and surrounding areas. The map was adopted from Futurism [2].**

To against the pollution, the popularity of a bike-sharing program has shown a vital growth. It is used by commuters, tourists and urban dwellers [10, 11]. One of the methods, China applied digitalized dockless bike-sharing (DBS). This is a shared bikes and now it becomes the third major mode of public transit [12]. The Chinese start-ups launched the world's first dockless bike-sharing system, which allows bike riders to share the bikes by using an app to search the bikes available in the city, unlock and pay the bikes with their smartphone [13]. DBS is becoming the main ideas for connecting transportation tool in urban areas. Further, it keeps the people fit, healthy, and effective addition to public transport because of its convenient, environmentally-friendly, and economically cost-effective [14, 15].

Toh [16] explained that according to the statistics, 45 DBS operators has been activated in China and they moved more than 7 million bikes. The number has increased to almost 60 startups of DBS operators by the end of 2017. There are two major bike-sharing providers, which are known as Ofo Inc. and Mobike Technology Co. Ltd.. They dominated the domestic market for DBS. Further it takes more than 80% of total market share. This innovative system of DBS is spreading and expanding globally to more overseas regions. For example, Ofo has shown DBS in more than 200 cities in 20 countries. Mobike has shown over 8 million DBS in more than 200 cities in 12 countries. Mobike also has well known in the United Kingdom, Singapore, Italy, Germany, Japan, United States, and Australia as other country markets begin to adapt this new startup trend [17, 18]. DBS industry is increasing in overseas users, and further can increase from five to 10 times in the next years [14, 19].

Based on studies by Yiyun [20] and Shi et al. [21], possessing great potentials, DBS is also facing some challenges such as illegal parking, blocking sidewalk, oversupply, vandalism, theft, and inaccuracy of GPS information that must be addressed to ensure that it is able to be better and become more stable. This paper is interpretative research on the statement of the world's first digitalized DBS systems in China, with the focus on technological innovations. DBS is a breakthrough program; thus, there have only been a few previous research studies on this matter. In this research, we can get more insight into the experience of respondents (especially foreigners) about the DBS program, which can then be applied better in other places with the same problems.

## 2. Theoretical Framework

### 2.1. City's air quality: the importance of air pollution management

China has been known as one of the world's largest energy consumers. China has rapid urbanization and development of transport infrastructure, as well as vehicle exhaust pollution. China also aggravated in its country. Energy consumption, including consumption of fossil fuel, is the main reason for the increases in air pollution emissions [22, 23].

China has been heavily polluted with high concentrations of chemicals (i.e., sulphur dioxide ($SO_2$)) as well as total suspended particles (TSP). This occurs especially when compared to WHO guidelines that assess air pollutant concentrations in large countries and developing cities reach a level of concern for public health (Table 1) [24]. More than three quarters of the urban population has air quality that does not meet China's national ambient air quality standards. The highest pollution levels and the occurrence of smog episodes, namely episodes with high concentrations of PM2.5 and low visibility, are seen in densely populated city groups in the Beijing - Tianjin-Hebei region, Sichuan valley, Yangtze River Delta. In general, urban air quality is worse in rural areas than that in coastal areas and worse in the north compared to the south [25]. The Chinese government has developed several national strategies to tackle regional air pollution, and public health is a matter of consideration, in combination with environmental problems. In 2016, the Central Committee of the Chinese Communist Party and the State

Council issued a "Healthy China Plan of 2030", which emphasized improving the management of environmental problems related to health [26, 27].

**Table 1. Sources of air pollution, effects and World Health Organization guidelines for selected pollutants. Table was adopted by Hidalgo and Huizenga [26].**

| Pollutant | Major sources | Effects | Health Guidelines (WHO 2002$_a$) |
|---|---|---|---|
| **Carbon Monoxide (CO)** | Motor-vehicle exhaust; some Industrial processes | Poisonous to humans when inhaled. CO reduces the oxygen carrying capacity of blood and places additional strain on the heart and lungs | 10 mg/m$^3$ (10ppm) over 8 hrs<br>30 mg/m$^3$ over 1 hr (30,000μg/m$^3$) |
| **Sulphur Dioxide ($SO_2$)** | Minor contribution from mobile sources. Heat and power generation facilities that use oil or coal containing sulphur; sulphuric acid plants | A human irritant, $SO_2$ undertakes atmospheric reactions to contribute to acid rain | 20 mg/m$^3$ over 24 hrs<br>500 μg/m$^3$ over 10 min |
| **$PM_{10}$ particulate matter** | Soil, oceanic spray, bush fires, domestic burning motor vehicles, industrial processes and organic dusts from plant material<br>Added some fuels, Pb is emitted from motor-vehicle exhaust; lead smelters; battery plants | Contribute to haze increases cancer risk, morality effects, aggravates respiratory illness<br>Affects intellectual development in children; many other adverse effects | 50 mg/m$^3$ over 24 hrs<br>20 μg/m$^3$ annual mean |
| **PM2.5 particulate matter** | Soil, oceanic spray, bush fires, domestic burning motor vehicles, industrial processes and organic dusts from plant material<br>Added some fuels, Pb is emitted from motor-vehicle exhaust; lead smelters; battery plants | Contribute to haze increases cancer risk, morality effects, aggravates respiratory illness<br>Affects intellectual development in children; many other adverse effects | 0.5 μg/m$^3$ over a year |
| **Lead (Pb)** | Soil, oceanic spray, bush fires, domestic burning motor vehicles, industrial processes and organic dusts from plant material<br>Added some fuels, Pb is emitted from motor-vehicle exhaust; lead smelters; battery plants | Contribute to haze increases cancer risk, morality effects, aggravates respiratory illness<br>Affects intellectual development in children; many other adverse effects | 200 mg/m$^3$ over 1 hr for $NO_2$<br>40 μg/m$^3$ annual mean |
| **Nitrogen oxides (NO, $NO_2$)** | A side effect of high combustion temperatures causing bonding of nitrogen and oxygen in motor vehicle exhaust; heat and power generation; nitric acid; explosives; fertilizer plants | Irritant, precursor to photochemical smog formation | 100 μg/m$^3$ over 8 hrs |
| **Photochemical oxidants (primarily ozone [$O_3$]; also peroxyacetyl nitrate [PAN] and aldehydes)** | Formed in the atmosphere by reaction of nitrogen oxides, hydrocarbons, and sunlight | An irritant, Photochemical oxidants contribute to haze, material damage, and aggravates respiratory illness | |

## 2.2. Bike-sharing worldwide

One of the critical problems in any mode of transportation is distance displacement, the problem is about how people continue their journey from public transportation to their final destination, this problem is called the last mile problem [28, 29]. Some researchers [30] refer to Last Mile Problem (LMP) to provide travel services from home or work to the nearest public transportation node ("first mile") or vice versa ("last mile"). The standard solution for LMP is to walk, take a taxi or motorcycle taxi, or drive a private vehicle. For many people, bicycles can provide fast trips to work but are often hampered by unattractive or unsafe bicycle facilities [31]. The bicycle is transportation that is quite popular from time to time in handling the latest mileage problems in some places of the world [32]. Nowadays people have more choices, including sharing bicycles [29].

Recently, DBS has shown its popularity (see Fig. 2). The number of public-use bicycles available known as DBS around the world has been increasing. Further, it reaches more than three times in the range of between 2013 and 2016 [33]. Indeed, by the end of 2016, it can be nearly 2.3 million bikes available to the public around the world. Then, 1.9 million of DBS are located in China. With 430 DBS programs, China becomes the leader for the use of DBS [34]. Ofo has shown the world had 23 million shared bikes, ten times higher than in 2016, in 304 global cities with nearly 400 million registered users, and this has been confirmed by Chinese Academy of Transportation Sciences of Ministry of Transport in December 2017 [35].

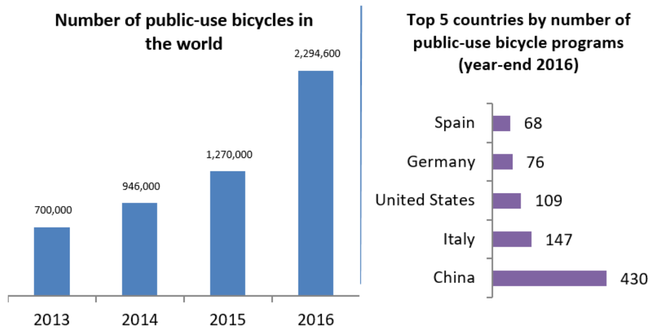


**Fig. 2. The global rise of bike-sharing. Figure was adopted by Richter [33].**

## 2.3. Innovation of DBS for city's air quality as sustainable transportation

Innovation has an important role in encouraging competitiveness. Innovation is the key to making the transportation sector more efficient and competitive. Companies that are innovative in their approach to productivity performance and using the latest technology gain advantages for increasing efficiency [36]. Compared to traditional public bikes with fixed parking docks, this bicycle sharing system with a model of sharing bicycles without docks is seen as an innovative and valuable approach to growing clean and energy-efficient travel modes in urban areas, and the solution to the problem of sharing dock bikes. This is because dockless bike-sharing does not require a fixed dock, lock and service terminal, instead, it can be accessed via GPS on mobile phones, and cellular payments to lock / unlock and pay by scanning the QR code on a bicycle in the smartphone application, which gives user comfort and flexibility. The survey results show that more than 90% of users believe DBS will be the future trend of the general bicycle industry [37].

Sustainable transportation is divided into two perspectives [38]. One perspective is related to sustainable development, which includes social, economic and environmental indicators for sustainable transportation to the world population without damaging the environment. The other perspective examines the sustainability of the transportation system itself, focusing on positive and negative values and traffic externalities [39]. Another study presents sustainability factors as environmental sustainability, social sustainability, institutional sustainability, and economic sustainability [40]. There are three dimensions and indicators for sustainable transportation, namely: environmental effects (noise pollution, energy consumption, land consumption, air pollution); social effects (public health, user ratings, affordability, accessibility, sustainable safety and security, additional facilities provided); economic effects (household expenditure allocated to transportation, transportation emissions costs, productivity, transfer time, transportation costs and prices, additional employment opportunities, economic efficiency) [41].

A long-term strategy is a good method, such as building a green ecosystem. It will also produce significant new demand in the case of environmental-related management. Indeed, it provides new business opportunities for environmental-related protection and industries as well as low-energy consumption industries [42]. Further developments in the sustainable mobility are important for reducing in the inefficient use of private vehicles. This can increase access to environmentally sustainable transport, specifically for communities with a high percentage of low-income households [43].

The boost of the DBS business has significantly released the bike travel demand in China and improved the mobility mode share structure in the cities and the air quality as well. Shaheen et al. [44] proposed that it plays a significant role in promoting the goals of sustainable urban travel and carbon emissions reduction. This seems perfectly filled up the gap of lacking efficient short distance transportation and promoted better adoptions of public bike-sharing systems in China. On the other hand, it also brings negative social effects, mainly problems lying in ethical aspects and management of the bikes, which might become barriers for future developments in urban mobility. Therefore, good strategies, which help improving negative social effects are necessary for creating better social sustainability. This study was to demonstrate a DBS such systems for being sustainable and making a contribution to the environmental and social sustainability.

## 3. Research Methods

This study used primary and secondary research methodologies. In primary research, the authors found more specific data about the respondents' experiences regarding the impact of DBS as sustainable transportation for environmental, social, and economic dimension in respondents’ perception through the questionnaire, and interview. On the other hand, secondary research supports theories from cases that are examined from a broader side. The sources used are books and journals, as well as other literatures such as trade literature, marketing literature, other product/promotional literature, annual reports, and security analyst reports. Then, questionnaire and interview were conducted with random people with a diverse occupation such as students, professionals, workers, etc., in which, there are from several cities in China, comprising foreigners and Chinese citizens. The obtained number of sample is 203 people. The method used a likert scale and based on the ease (convenience sampling).

$$z^* \sqrt{\frac{\hat{\rho}(1-\hat{\rho})}{n}} = 1.645 \sqrt{\frac{(0.86)(0.14)}{203}}$$

$$= (1.645)(0.024) = 0.039$$

According to the data, it is concluded that 86% of the respondents reported that they know about DBS in China and tried to use it in public space (as much as 3.90%). For further research, it is recommended that the number of sampling be expanded.

For further understanding from consumer perspective about the DBS as the sustainable transportation in China, the survey was conducted for 2 months where the location covered in some cities in China; Beijing (30), Shanghai (30), Guangzhou (30), Hangzhou (50), Wuhan (26), Xi'an (27), and Harbin (10). In total, 203 surveys were completed. The limitation in the research methodology was constrained by the language, in which, the researchers were incapable of speaking Mandarin so that sampling could not be carried out maximally because the researchers used English and only very few Chinese respondents were willing to be questioned.

## 4. Results and Discussion

According to the results on demographic variables based on the age indicator, it is obtained that the majority of the respondents are between 25-34 years old (55,67%) and 18-24 years old (37.44%) who are undergraduate and graduate students (74.88%), with the revenue of between RMB 2,001 and 4,000 per month (67.98%). This indicates that students are the largest potential market for DBS within the middle-income range whose travel purpose is to go to school (51.72%). The respondents are foreigners (93.1%) and Chinese citizens (6.9%) based on convenience sampling. 86.21% of the respondents reported that they know about DBS in China and tried to use it in public space. 78.82% of them prefer to choose Ofo, but only 64.53% of them own the account of a DBS program. From the observation, some of the respondents will use their friends' account to unlock the bicycle because one account can trickily unlock more than one bicycle.

The majority of respondents (47.78%) use the DBS for 10 to 20 minutes. Accessibility (36.45%) affected their priority of choosing sharing bikes. It allowed the users to search sharing bikes in outdoor location instantly. 19.21% of the respondents were concerned with bike comfortability and 14.78% of them showed the bike environmental friendliness and free of rental cost (12.32%) affected their bike's selection.

32.02% of DBS users talked about this system can bring healthy life. It also promotes excellent program for green transportation (20.69%). It can bring happiness to their communities and provide harmonious atmosphere. In contrast, the respondents reported the difficulties that prevent them from using DBS (Fig. 3). The quality of the bicycles was the highest reason to prevent users from using bike-sharing. Some of the bikes were damaged by the previous user(s), some were designed in heavyweight that they were difficult to control by the users. Some bicycles were seen abandoned and damaged without maintenance. The company should be able to detect damage reported from the application and conduct feasibility inspections every day. This can also provide employment opportunities as seen from the number of bicycles scattered in each city. In general, the majority of respondents shows the health, environmental benefits, and convenience are the most important factors in dictating user's choice of DBS [44].

According to respondents' perspective, DBS as a sustainable transportation gives a positive effect on the environmental dimension to decrease air pollution, energy consumption, and noise pollution. On the social dimension, respondents assumed that DBS as a sustainable transportation give an effect to increase public health and accessibility [45]. Bike sharing also decreases transport emission cost and transfer time on economic dimension.

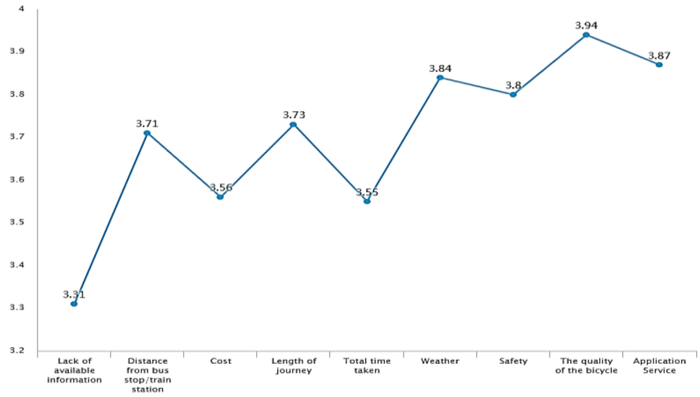


**Fig. 3. The factors that prevent users from using DBS.**

The respondents aware of environmental issues that global warming is caused by human activities, and they would be willing to ride a DBS to help improve air quality (Fig. 4). Lastly, it produces the public on using green multimodal transport connects. It acts as the last mile connection to public transportation. Health advantages and individual financial, as well as time savings are obtained while DBS is introduced in the community [46, 47].

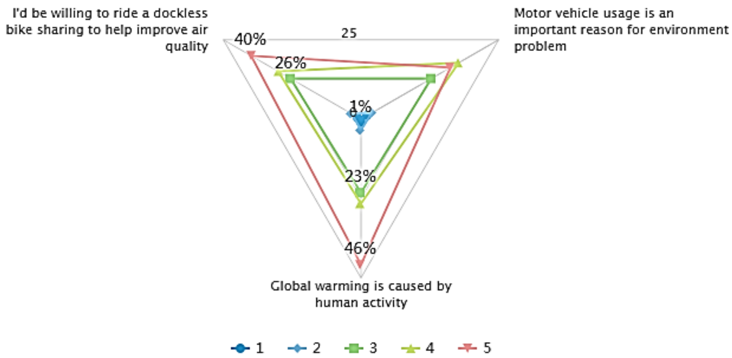


**Fig. 4. Respondents' perspectives of environmental issue.**

The effects on air pollution and traffic from bike-sharing have been positive. Recent study that was developed by Mobike [48], indicates that the number of trips by cars (including those by private cars, taxi, and car hailing apps) in China has been decreased by 55% since the introduction of bike sharing. Cycling has increased in popularity by over 100%, which also means bike-sharing urban carbon footprints, reducing carbon emissions by 540,000 tonnes and then made the air quality improvement and energy conservation efforts [47]. DBS will create more environmental-related advantages by reducing energy use as well as emissions in the transport sector [48]. It also releases the traffic pressure [49].

Increasingly, DBS is popular in China and it has help ease traffic congestion. It can be approximated more than 80% of China's 100 biggest cities. It presented and improved a solution for local traffic conditions [13]. Xinhua [50] explained that indeed, as a result of DBS, it can be calculated that 7 trillion tons of carbon emissions have been reduced. The Chinese Ministry of Transport calculated that DBS reduced the costs of congestion in China by 16.1 billion yuan (£1.81 billion). Then, adding this value to other perspectives, further benefits can be obtained such as an additional 200 billion yuan (£22.5 billion) in other social factors [51].

## 5. Conclusions

DBS shows an excellent example for green application in travel. It is an innovative solution to address the demand for the environmental problems but at the same time, it can be a problem solver for people to be mobile in the urban environment. The data show that the air quality of the city is increasing since China implement the digitalized DBS program and become a solution of the 'last mile' problem in transit transportation. It plays a significant role in promoting the goals of sustainable urban travel and carbon emission reduction. The respondents mostly agree that DBS can represent a good example in the environmental, social, and economic dimensions and become sustainable transportation. Although DBS systems in China are growing, further spreading in worldwide, and being demonstrated for the potentiality in reducing greenhouse gases and fuel consumption by discouraging personal vehicle use for people's mobility, their future demands and long-term sustainability are uncertain. Thus, more in-depth comprehension as well as research on DBS are still required. To solve the difficulties, the market alone is inappropriate. It requires collaborative efforts from the government, the bike operators, as well as the users. But, it must be under a regulatory framework. By adding this system, DBS plays its own roles for cooperation and mutual development. Further researches will bring more significant contribution if more balanced sampling can be carried out with Chinese respondents.

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