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The Car Use Reduction Potential and Modal Shift Impacts of Dockless Bikesharing System - A Case Study of Beijing, China

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Abstract

Dockless bikesharing systems are not only a billion-dollar business but are also supposed to be the solution to a variety of the world's most pressing problems in urban environments. It is not only a sustainable, efficient, healthy and convenient way of transportation but also bears many environmental and socioeconomic benefits that can supposedly solve the "first and last mile" problem. Even though bikesharing has been around for more than half a century, due to the development of the fourth generation bikesharing, there has been a recent explosion in the number of shared bikes as well as bikesharing programs. Dockless bikesharing is especially popular in China which is home to more than half of the global bikeshare fleet, however, research activity does not reflect this. Much previous research has tried to assess the impact of bikesharing on the reduction of car use and whether it causes people to change their travel behavior. Yet, no consensus has been found among researchers. To fill this research gap, this paper analyzed the modal shift impacts of dockless bikesharing in Beijing through an online survey. Results show 85% of the respondents have at least replaced some of the trips they have previously done by car with bikesharing in combination with public transport services. Furthermore, one out of five respondents now drive a car less frequently and more than half use taxi or car sharing services less often as a result of using bikesharing. Despite all the problem of dockless bikesharing, from a societal point of view, the benefits of bikesharing definitely outweigh the negative aspects and cannot only completely change the way we travel but also improve the living quality of many people.

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I. Introduction

Dockless bikesharing systems are not only a billion-dollar business but are also supposed to be the solution to a variety of the world's most pressing problems in urban environments. In less than two years, the number of shared bike users rose from merely 28 million to 209 million in China alone and the streets of Beijing are filled with more than 2.35 million shared bikes to rent from 15 different companies as of 2017 (Yang, 2017). Not only is cycling a more sustainable and "green" mode of transportation but it is also faster and more convenient compared to walking or taking the bus while providing increased reliability. In contrast to taxi and private bicycles, travel costs are reduced, and users do not need to worry about theft and maintenance (Zhou, Ni, & Zhang, 2018).

While some researchers speak of the use of shared bikes as an efficient alternative and competitor to public transit, from the government's point of view bike sharing provides an affordable complement to the public transport system and creates welfare for the citizens (Lohry & Yiu, 2015). In addition to relieving the load on the transport network, bike sharing systems also lead to a reduction in carbon dioxide emissions (CO_2) as well as road congestions by reducing private vehicle usage. Increasing bikesharing is also considered as a good strategy to tackle health and obesity issues (Friedman, 2017). Through the use of shared bikes, users, especially low-income commuters, can also cut down their travel time and save costs thus making transportation affordable and attainable for people of all incomes (Friedman, 2017).

Bikesharing is not a new concept and has been around for several decades. The traditional form of bikesharing consists of bikes that can be rented from fixed spots in the city and have to be returned to those so-called docking stations. Nowadays, the recent growth of bikeshare and what has ultimately led to a revival of bicycle use around the world is the fourth generation of bikesharing systems. Characterized by its dockless nature which can be accessed by people from everywhere (Zhang Y. , 2017), they provide greater flexibility and increased convenience for its users compared to shared bikes with fixed docking stations (Chang, Song, He, & Qiu, 2018).

What is remarkable and groundbreaking about shared bikes is that they have "the potential to change user behavior, […] in the same way that people who would never have previously even ridden a bike might now consider riding one" (Jordan, 2018). Many previous studies have found that bikesharing systems across many cities including in Beijing, Shanghai, and Hangzhou can encourage modal shifts and induce users to switch from public transit and trips made by car to bikesharing (Zhu, Pang, Wang, & Timmermans, 2013). However, other researchers obtained data that suggest this is seldom the case and the effect of bikesharing in replacing private vehicle trips has been less than expected (Fishman E. , 2016).

In fact, evidence from London, Washington DC and Dublin have shown very low modal shift rates from private vehicle trips to bikesharing systems (Fishman, Washington, & Haworth, 2013) and if people cycle instead of walking, then there are no reductions in greenhouse gas emissions (GHGs). Furthermore, the environmental effect can even be negative. If many people stop using public transit especially in low-density areas, it can become financially unsustainable resulting in cutbacks of less profitable, unattractive routes (Reinhold & Kearny, 2008). Due to a cancellation of those busses, former bus users who were still relying on the service might either start using the private car now or be more isolated than before if they do

not own a car. 1.5 million people are actually affected by "transport poverty" In the UK alone (Poverty and Social Exclusion, n.d.). Especially, older or handicapped people might be negatively affected, and it could result in a decrease in their accessibility and quality of life leading to higher social costs. This is an issue that affects many countries since public transit networks have to reach a certain minimum level of usage. Otherwise, they are underused and could become too expensive to operate.

There is no country that has the bikeshare scale of China with more than 64% of the global bikeshare fleet in Chinese urban areas as of early 2013 and by now this number has already increased even more (Larsen, 2013). Yet, research activity does not reflect this, and researchers need to put a much greater focus on Chinese bikesharing systems as its enormous scale, high population density and speed of expansion may provide interesting insights and valuable lessons for bikesharing operators and local authorities in other countries (Fishman E. , 2016). Therefore, this paper also aims to fill this research gap and extend the existing literature by examining the case of Beijing.

Like many other countries, China is suffering extremely from the negative consequences of an over-reliance on motor vehicles and the private car has become the primary mode of transportation. Due to increased living standards and a large proportion of the population becoming wealthier, ownership and the use of motor vehicles have increased dramatically in China (Zhao, 2014) causing high CO_2 and leading to unbearably high levels of air pollution (Zhang, Zhang, Duan, & Bryde, 2015). Many studies have proven that "long-term exposure to combustion-related fine particulate air pollution" is one of the main factors for lung cancer and cardiopulmonary mortality (Arden Pope III, et al., 2002). According to the South China Morning Post, there were nearly 4.3 million new cancer patients in China in 2015, and 730,000 cases were of lung cancer, accounting for 36 percent of the world's total (Reuters, 2017).

Due to the mixed conclusions on bikesharing's impact on modal shifts, it is therefore absolutely necessary to conduct further research to shed light on this issue. Not only the bikesharing operators but also the government need to understand when people actually change their travel behavior and what effects it might have on the society. Therefore, this thesis will contribute to the existing literature by examining the performance and impact of bikesharing more closely. If bikesharing systems are successfully integrated into the public transport system, it might be a cheap, convenient, healthy and green solution to all the aforementioned problems (Chang, Song, He, & Qiu, 2018). This makes it a highly socially and scientifically relevant topic that needs more attention from researchers. By carrying out this research and analyzing the case of Beijing, the knowledge gap which hopefully be filled. Therefore, the following research question is proposed:

To what extent does bikesharing reduce car use and what are the modal shift impacts in Beijing?

This thesis reviews recent literature across a broad range of topics concerning bikesharing, including recent trends of the sharing economy, the history and recent growth of bikesharing, its benefits, usage patterns, user preferences, operation models, barriers, and challenges. Papers examining the impacts of bikesharing are also reviewed, as well as the problems and challenges of rebalancing. Last but not least, an analysis based on survey data

from Beijing with the modal shift rates from public transit, walking, cars, and taxis will provide more insights on the how bikesharing is changing cities. Finally, the last section will draw conclusions, highlight the study limitations and provide recommendations for future research.

II.   Literature Review

Background information

    a. Sharing economy: shared housing, cars and now bikes

In recent years, the concept of the sharing economy has become increasingly popular and people's perception and attitudes towards sharing goods and services with strangers have changed considerably (Cohen & Kietzmann, 2014). People are not only willing to share certain things with their friends but also with people they have never met to contribute to our environment and making our world more sustainable.

There are many different business models associated with the sharing economy which are based on a collaborative consumption lifestyle including sharing living spaces, bikes, cars, and rides in general (Botsman, 2013). Especially sharing on-demand basis rides is just starting to gain widespread acceptance and market share and promises to mitigate a number of problems in densely populated cities struggling with limited space and population growth. Sharing vehicles create many benefits for the public good and urban sustainability such as reducing inner-city traffic, congestion and air pollution problems (Ma, Lan, Thornton, Mangalagiu, & Zhu, 2018). While some researchers argue that the success of these sharing business models was mainly driven by increasing environmental consciousness and a more economical way of spending after the global economic crisis in 2008, the digital technologies and how information and big data are analyzed have also contributed to it tremendously.

Especially, the diffusion of the Internet, higher smartphone ownership, and increased credit card penetration rate have facilitated the rapid development and scalability of sharing economy businesses (Zhang Y. , 2017). Those businesses often provide a platform acting as intermediaries between participants and thereby mitigating risks and building trust among strangers. By providing individuals with information and matching excess supply and demand for goods, resources can be used more efficiently. Furthermore, idle capacity is the foundation of the sharing economy (Tucker, 2017). The sharing economy utilizes the excess capacity created by the unused cars, bikes and living space and the resulting positive externalities associated with networking effects also benefit the society as a whole (Chris, 2017).

However, the sharing economy has also been criticized for not really being about "sharing" but more about consumers paying to gain "access" to other people's or companies' goods or services for predetermined period of time. Especially bikesharing has often been the target of discussion for not being part of the sharing economy because the operators own all the bikes and are responsible for the maintenance and replacement of bikes. In that sense no assets or costs are being shared between the users (Towson, 2017). In fact, bikesharing is heavily denounced for adding additional excess capacity by producing and dumping millions of bikes into the city instead of making use of the existing (private) bicycle fleet or replacing the private car. Not only does this lead to heaps of unused bikes being abandoned and thrown away creating many so-called "bicycle graveyards" but they also destroy the beauty and

aesthetic aspects of the city environment through overcrowding important locations (Mead, 2017).

On the other hand, Zhang Yanqi, the COO of Ofo, one of the largest bikesharing companies, disagrees. He explains that when Ofo was first launched at the campus of Peking University in Beijing, it was actually based on a model in which people would gain access to the system by donating their personal bikes. However, not many people were willing to do so, and demand for the shared bikes grew very fast. Hence, they started bringing new bikes to the consumers but those are bikes manufacturers were planning to sell to the market anyway (Zhang Y. , 2017). Zhang argues that shared bikes are 20 times more efficient than private bikes and his argument has been confirmed by findings from many other bikesharing systems such as in Antwerpen, Lyon, Hohot, Zhuzhou and Taiyuan where the average rental per bike per day is between 5 and 8.82 with Hohot being the most efficient system (Lohry & Yiu, 2015). A higher turnover translates into higher efficiency meaning fewer bikes are needed to provide the same mobility to users. Therefore, resources are actually being shared which is aligned with the idea of the sharing economy.

According to eMarketer, it is nonetheless true that many users seem to prefer "access over ownership" since ownership is often more expensive, and they just seek a cost-effective and convenient user experience (eMarketer, 2015). After all, it is an economic exchange where certain parties also make a profit. Consumers care less about building social relationships with other consumers or creating value for the society but more about maximizing their own utility (Eckhardt & Bardhi, 2015). This has important implications for the success and competition between companies operating in this sharing economy space. In accordance with this, companies which create the highest consumer surplus by providing maximum convenience at the lowest costs and the best value for money such as Uber can win over more customers and have a competitive advantage over firms providing identical services like Lyft that emphasize on the people and community aspect (Altrock & Suh, 2017).

US Adult Sharing Economy Users and Penetration, 2016-2021
millions and % of adult internet users

Note: individuals ages 18+ who have used their account for a community-based online service that coordinates peer-to-peer paid access to property, goods and services (e.g., Airbnb, Uber) at least once during the calendar year; excludes crowdsourcing, group buying, incorporated professional services and online marketplaces
Source: eMarketer, July 2017
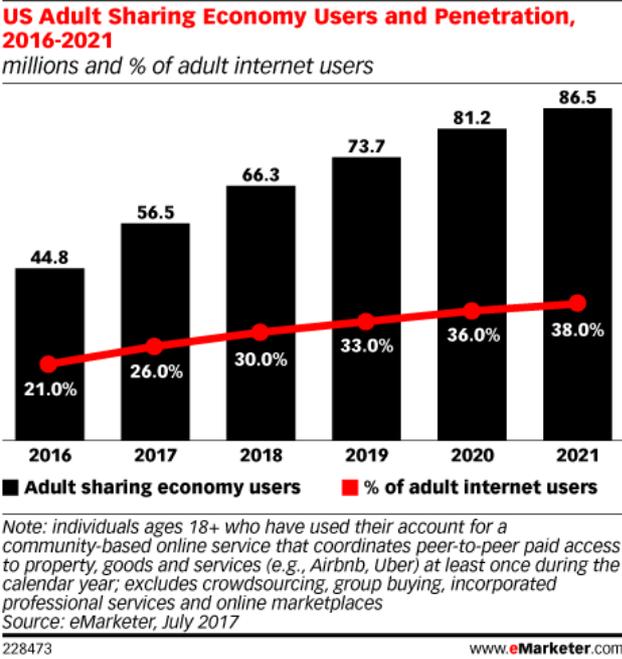228473   www.eMarketer.com

Figure 1 US Adult Sharing Economy Actual and Estimated Users and Penetration Rate, 2016-2021

b. History and Recent Growth

Up until now, there have been three bikesharing generations that ultimately led to the development of the fourth generation. The fourth generation is characterized by dockless bikes that can be picked up and left anywhere and do not need to be returned to fixed docking stations. This new generation was first introduced in China about four years ago and has since then attracted large media coverage. Reasons for this worldwide interest of dockless bikesharing is due to its increased flexibility and convenience. It can provide an even better solution to solving the "first and last mile" connection problem to other (public) transit modes compared to the previous generations and has the power to alter the way people commute in the city (Fishman E. , 2016).

c. Generations of Bikeshare

The first generation of bikesharing was originally a concept from the 1960s and the Witte Fietsen (White Bikes) were first adopted in 1965 in Amsterdam. This first attempt at providing bikes for public use failed miserably as there were no payment or security functions of the bikes. Due to vandalism and theft such as throwing the bikes into canals or people appropriating them for private use, the program collapsed only within a couple of days after its launch (DeMaio, 2009).

Thereafter, the second generation of bikesharing emerged in 1991 in Farsø and Grenå, Denmark but was relatively small with only a few bikes and stations (Nielse, 1993). Only in 1995, a larger scale second generation bikesharing program was introduced in Copenhagen based on a coin deposit system which was similar to trolleys at supermarkets. Even though there were many improvements compared to the first generation, theft was still a huge challenge due to the anonymity of users.

The third generation evolved as a result of the previously encountered problems of the first two generations and was first seen in Portsmouth University in the U.K. which was only intended for students to use on campus. This generation of bikesharing was characterized by many technological improvements including dedicated docking stations where bikes were picked up and returned, smart card payment (through magnetic stripe or credit cards) and bicycle tracking systems (DeMaio, 2009).

During the late 90s and early 00s, bikesharing only grew slowly and the breaking point in the bikesharing history was not until 2007 when Paris launched its own bikesharing program. That program attracted tremendous interest from all around the world including emerging economies such as Brazil and China (DeMaio, 2009). The fourth generation bikesharing system includes all the perks and main components of the third generation but is more focused on being a link to other (public) transit modes through its dockless nature. Due to many bikes being conveniently parked near transit stations, they facilitate the purpose of perfect integration with public transportation and other alternative modes including car-sharing and taxis (Shaheen & Guzman, 2011).
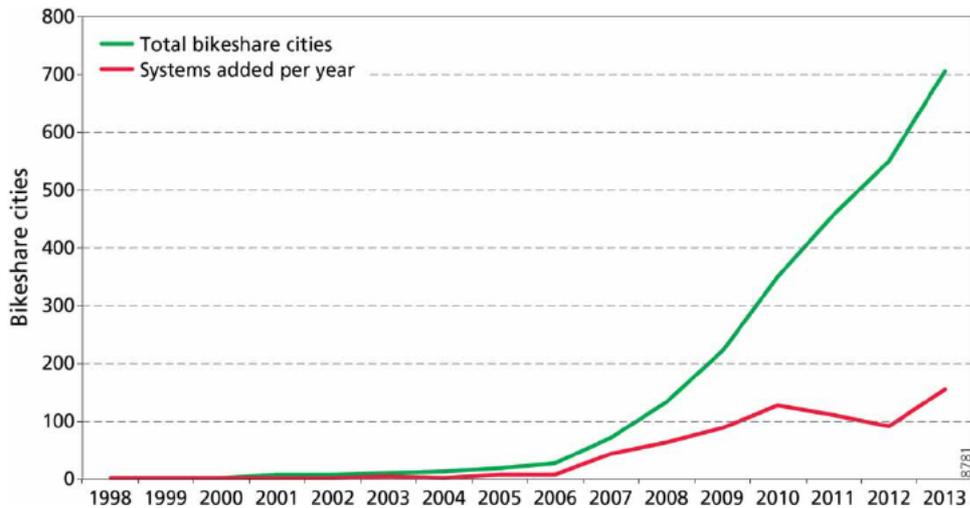
d. Bikesharing's Recent Growth

Figure 2 Growth in Bikeshare Cities (1998-2013)

Over the past 20 years, the number of cities with bikesharing programs as well as the global number of public use bicycles has increased drastically. From a mere 13 bikesharing systems in 2004, the number has jumped to 855 in 2014 and the number of shared bikes has reached more than 2 million by 2016 (Meddin & DeMaio, 2015). In China alone, there were an estimated 1,000,000 shared bikes in 2016 and this number has more than doubled reaching more than 2,35 million by the end of 2017. In the capital city, there are also more than 430 public use bicycle programs, twice as much as Italy which has the next closest number of bikesharing systems, at 147, and by far more than the US with 109, 76 in Germany and 68 in Spain (Meddin R. , 2017).
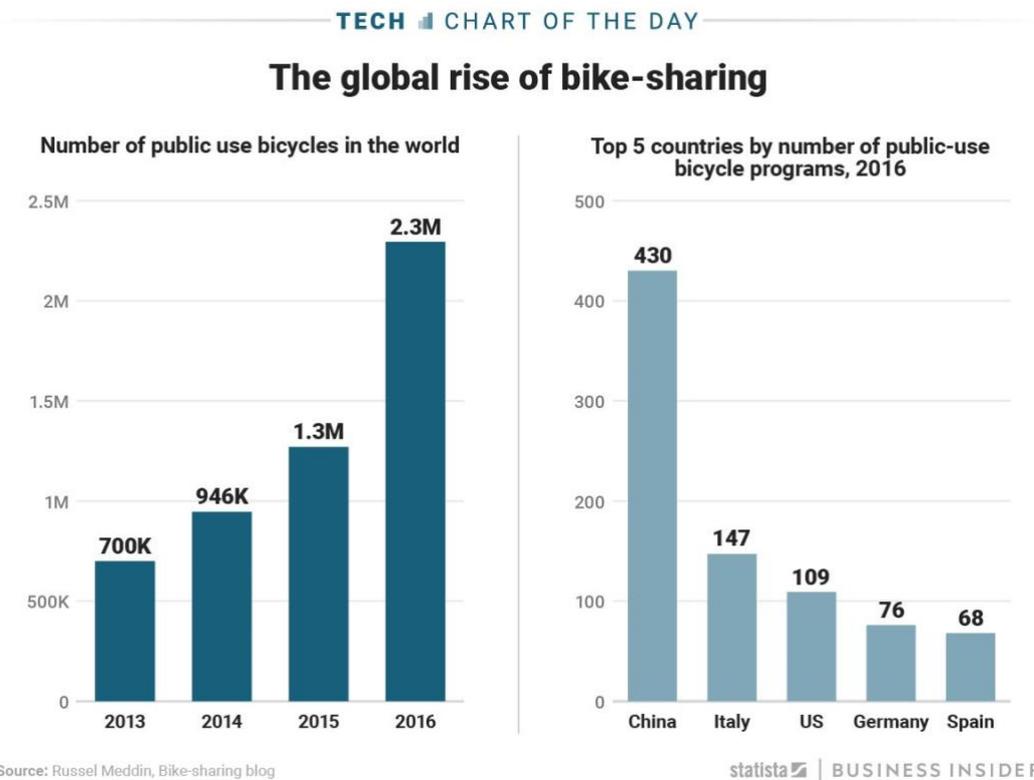

Figure 3 The Number of Public Use Bicycles in the World (2013-2016) and the Top Five Countries by Number of Public-Use Bicycle Programs as of 2016

Furthermore, even though bikesharing has become increasingly popular in Asia (Appendix Figure 1) and the number of bikesharing programs has been rising, it is remarkable that only two out of the top ten countries with the most bikesharing programs are in Asia, namely in China and Japan (Figure 4). With its sheer number of bikes, China is by far the leader in bikesharing as "three out of four of the world's bike-share bikes are in that nation" (Goodyear, 2015). The success of bikesharing systems in China could be due to a number of reasons which will be discussed more closely in the upcoming sections. Just to name a few, these reasons could include low production and labor costs, high population density, lower user charges compared to systems in other countries and the city infrastructure.
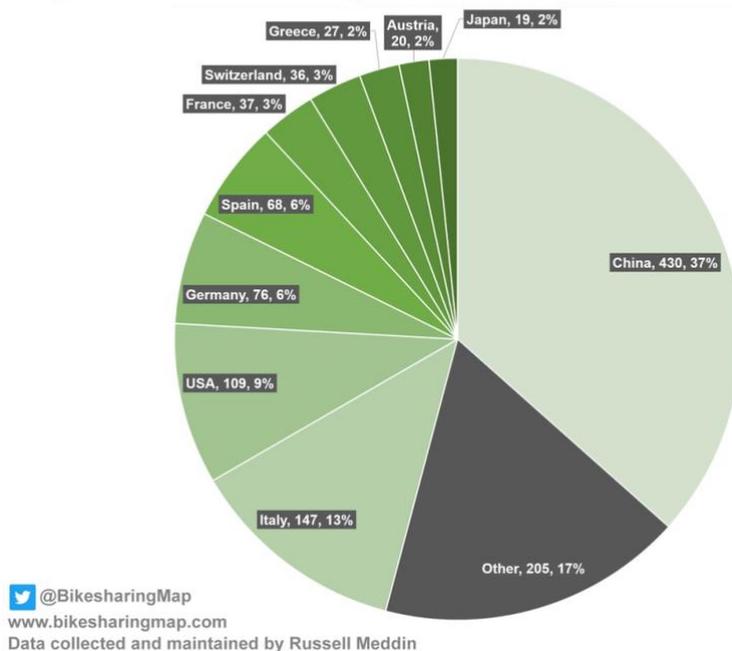

Figure 4 Number of Public Use Bicycle Programs of the Top Ten Countries, 2016

Multiple benefits of bike sharing systems

One of the reasons why bikesharing has become so widespread and popular worldwide are the multiple benefits associated with bike sharing systems and cycling in general.

a. Environmental benefits

Due to increasingly higher living standards, a growing middle class and increased affordability of cars in the last decades in China, vehicle ownership and in particular car ownership have been rising. Car traffic, as well as the total number of kilometers, traveled in private cars increased drastically which might be caused by the comfort, speed, and convenience it provides and that there is no equal substitute. Contrary to Europe or North America, a car is rather seen as a status symbol representing fortune and social class than just a form of transportation said Hu Xingdou, economics professor at Beijing Institute of Technology (Watts, 2011). In a generation's time, China, which has been known as 'the kingdom of bicycles' for decades, has transformed itself into a lucrative market for many foreign luxury car brands.

Whereas in the 1980s, a bike was considered as one of the 'must haves' for couples getting married, the private car has replaced the bicycle and also its role for commuting and transportation purposes (Zhao, 2014). In many densely populated Chinese cities where congestion has become a day to day norm, roads are clogged with supercars. Despite the average rush-hour speed of around 25kmph in the capital city, the luxury car market with 300kmph cars shows no sign of decline (Addison, 2009).

According to IBM's Global Commuter Pain survey, 95 and 84 percent of respondents in Beijing reported that roadway traffic has negatively affected their health and work or school performance respectively. Furthermore, seven out of 10 drivers have even turned around and given up on reaching their destination because the traffic jam has been so bad in Beijing (Plant, 2010).

China has also been experiencing large economic losses due to congestion and the resulting air pollution and health issues (Lohry & Yiu, 2015). Therefore, reducing car use and finding feasible alternatives which can relieve the transportation network are necessary for creating and maintaining a sustainable urban environment. To mitigate the negative effects of congestion, local authorities have made use of behavioral economics principles to change people's behavior such as informing the car drivers about the fuel costs they have incurred after each ride they have taken.

Based on the diminishing sensitivity to gains and losses, one of the four basic elements of Prospect Theory, developed by Kahneman and Tversky (1979), the psychological damage and emotional effect of having to pay the fuel costs is higher than the fulfillment from gaining the same amount of money (Kahneman & Tversky, 1979). Therefore, being constantly reminded of this information creates awareness and urges the drivers to try to minimize these costs. As a result, the car users save costs for themselves through increased physical activity, but other drivers and the society will also benefit from less congestion and a reduction in CO_2 emissions (Assem, 2013). Furthermore, a number of transport demand management strategies (TDM) have been implemented as well (Gärling, et al., 2002). Examples of adopted TDM strategies in China include vehicle quota systems, number-based license restrictions and parking management (Lohry & Yiu, 2015).

In summary, researchers have argued that public bikesharing programs are one of the best ways to help reduce car use as it strengthens the public transit network and can act as a complement to existing metro and bus systems. The Institute for Transportation and Development Policy has previously estimated the potential total reduction in emissions from urban transportation could be up to 50% but only if cities would actively implement policies promoting sustainable alternative travel modes (Schmitt, 2015).

If the impact of bikesharing on modal shifts is as large as some researchers have claimed, then it could possibly lead to noticeable GHGs reductions. Nevertheless, increasing cycling activities alone will not be sufficient to reach "the goal of limiting climate change below 2°C" (European Commission, 2011). According to the World Resources Institute, about 70% of the world's GHGs originate from cities and the transport sector is also an increasing source of GHGs (Jiang, 2018). To reach the climate change goals of the EU, the transport sector needs to cut its GHGs by at least 60% by 2050 (European Commission, 2011). But exact estimations of CO_2 emissions in transportation are difficult to make considering that several assumptions

and boundary conditions and many different approaches how to estimate emissions exist (Rudolph, 2014).

Even though bikesharing is extremely attractive as a result of its flexibility and low usage costs, it is mainly limited to short distances. However, the environmental benefits are especially prevalent when bikesharing systems are integrated with a city's public transit system, thereby extending its use to larger distances which are not limited to the city center alone. A combination of bikesharing and other transport modes does not only encourage the use of public transport but also facilitates multimodal transport connections (Lohry & Yiu, 2015).

a. Socioeconomic benefits

Apart from the environmental benefits and cost savings for its users, bikesharing systems also bear an abundance of socioeconomic benefits. Bikesharing cannot only lead to modal changes through the ease of multimodal trips but also facilitates people to undertake trips they previously did not undertake (Jordan, 2018). Thus, bikesharing creates a number of new trips in addition to solely replacing or reducing car and public transit use and enriches people's lives. It is also an excellent way to solve transport poverty through providing accessibility and connectivity to rural communities such as the outskirts and suburbs in London (Velaga, Beecroft, Nelson, Corsar, & Edwards, 2012). In Washington DC and in Berlin bikesharing also increases the accessibility to jobs and education because more jobs and schools can be reached within a 30-minute commute (Mobike, 2018)

Bikesharing is effective and efficient way to overcome short distances that are too long to walk but too short for driving or taxi services. Thus, many people use bikesharing services to travel between their home or workplace and the nearest public transport station. This is also known as the "first and last mile" problem and bikesharing has often been quoted as an effective solution due to its low cost and flexible character (Shaheen, Guzman, & Zhang, 2010). Furthermore, bikesharing users do not need to bear the risks and responsibilities of owning a private bicycle. The aforementioned can be especially handy because users do not have to deal with the repair/replacement costs in case their bicycle has been damaged or stolen.

In addition, evidence suggests that bikesharing can also create social benefits for communities such as increasing the accessibility of low-income groups in London. Even though only a small proportion of trips are made by users from 'highly-deprived areas', an adequately priced and affordable bikesharing system can encourage residents of poorer areas to use shared bikes more frequently (Goodman & Cheshire, 2014). Thus, placing dockless bikes into these neighborhoods makes them attractive and keeping the usage fee relatively affordable compared to other alternative travel modes is especially rewarding. Therefore, in order to maximize a bikesharing program's ability to create benefits and make transportation more equitable, bikesharing needs to be accessible in both rich and poor neighborhoods and have affordable prices.

Furthermore, introducing 'casual' trips along with trips just for commuting purposes also encourages the participation of female users (Goodman & Cheshire, 2014) as researchers have found that there is a significantly higher proportion of male users among many cities' registered users of bikesharing schemes (Fishman E. , 2016).

b. Health benefits

There have been a number of studies carried out that investigate the health benefits and risks associated with cycling and reduced car travel. Although there are a number of health benefits when people switch from motor vehicles to cycling, due to the higher levels of physical activity, there are also some health risks that cannot be ignored in the analysis. The most prevalent ones are caused by a higher exposure to pollution and a risk of traffic accidents (Hartog, Boogaard, Nijland, & Hoek, 2010). Speaking of bike accidents, one of the biggest constraints to cycling is people being concerned about their safety when cycling. Especially in countries with lower cycling and higher car use rates and a larger gender disparity in bicycle use, safety concerns are a major barrier to bicycling (Garrard, Crawford, & Hakman, 2006; Goldsmith, 1992).

Nevertheless, from a societal point of view, the estimated overall health benefits from users engaging in more cycling activities outweigh the risks. The resulting reductions in air pollution, GHGs and fewer (car) accidents lead to a positive net effect on the public health of the society (Hartog, Boogaard, Nijland, & Hoek, 2010). As Nazelle, Tainio, and Nieuwenhuijsen (2011) have shown in their health impact assessment study based on Barcelona's public bicycle programme with 182062 people (11% of the population in the municipality of Barcelona) subscribed by August 2009, the annual number of deaths avoided decreased by 12.28 from 52.15 to 39.87. As a result of the increased physical activity and a higher number of cycling journeys, there is an estimated reduction in CO_2 emissions of 9 062 344kg (Nazelle, Tainio, & Nieuwenhuijsen, 2011). These results were also confirmed by other researchers. In a study it was estimated that the total benefits and savings from avoided mortality and reduced health care costs due to better air quality and improved physical fitness to exceed $8 billion/year in the US alone simply by replacing 50% of short car trips with cycling (Grabow, et al., 2012).

Furthermore, cycling also increases the cardiovascular activities and helps to reduce the risk of diabetes (Handy, Wee, & Kroesen, 2014). Especially in China, where almost half of the Chinese adults have prediabetes or diabetes, the associated benefits of increased physical activity could potentially reduce health care cost significantly (Jenkins, 2017). Results from a nationwide cross-sectional analysis conducted in 2013 showed that about 11 percent have a high prevalence of diabetes and roughly 36 percent have prediabetes. With roughly 1.09 billion adults living in China, about 388 million people are estimated to suffer from prediabetes (Wang, et al., 2017).

Considering that bikesharing is also a form of cycling and it has the potential to encourage people to start riding a bike who have previously not done so (Jordan, 2018), it can completely change how people commute and travel and improve public health tremendously across the world.

Problems of the fourth generation of bikesharing: dockless system

a. Sidewalk clutter and oversaturated supply of bikes

With increased convenience and flexibility, the fourth generation of bikesharing brings, there are also a number of severe problems it is currently facing. In cities with a high population density, where pedestrian space such as sidewalks is insufficient, the dockless bikesharing system will most likely not be able to expand at its current pace. Either the operating costs

will be too high, or the rebalancing and distribution of shared bikes will be too slow causing people unable to use it or there will actually be an oversupply of bikes causing sidewalk clutter (O'Brien, 2018). The latter one is currently posing an extreme challenge to the Chinese government.

As the number of shared bikes approaches a million in several cities each, over a dozen local authorities have already banned the issue and deployment of new shared bicycles including in Guangzhou, Beijing, Shanghai, Nanjing, Hangzhou, Fuzhou, Lanzhou, and Zhengzhou (Nakamura, 2017). Thousands of broken and unused bicycles have been dumped in suburbs and have been abandoned in abundance creating "bike graveyards" across China (Zhecheng, 2017).

Figure 5 Dockless Bike Graveyard

b. Theft, vandalism, and quality of bicycles

Theft and vandalism have always been posing a great challenge on bikesharing companies ever since the first generation of bikesharing (DeMaio, 2009). Over the years and with technological advancements such as smart locks and GPS location tracking, the damage and loss have been mitigated. However, not all bikesharing operators also make use of the smart-lock technologies. As opposed to most bikesharing companies, Ofo, one of the largest operators, uses a mechanic locks for its bikes. With no GPS tracking, Ofo users cannot access the location of the bikes and it depends on pure luck to find one causing a lot of frustration for users. Furthermore, with the simple mechanic lock, the pin that users need to enter to unlock a bike upon scanning the QR code of the corresponding bike does not change.
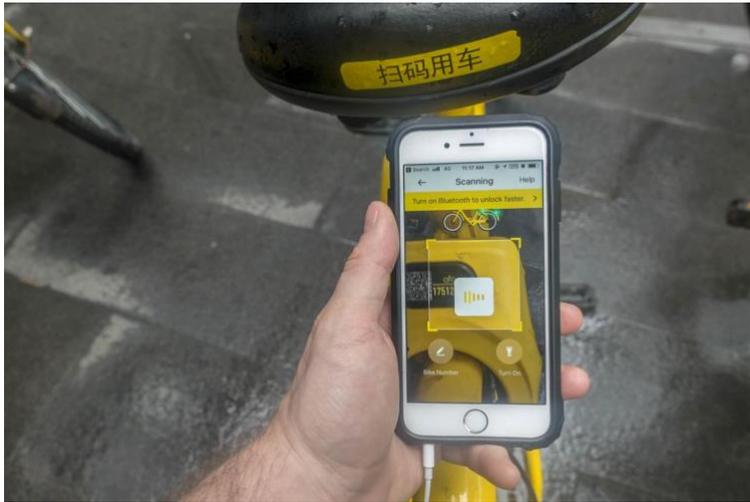
Figure 6 Unlocking a Dockless Bike from Ofo Through Scanning the QR Code

Despite the disadvantages of Ofo's simple bicycle model, this strategy also has its benefits. In addition to having an extremely high expansion rate, they reduced their production time, and cut down their production costs by 50 percent compared to other bikesharing operators.

However, Ofo's fast success did not come for free and their fast expansion strategy also has its downsides. Media has reported many cases of theft and users' irresponsible handling of the shared bikes. One of the reasons is the lack of GPS location tracking which is why once a bike is put out there, it is extremely difficult for Ofo to find and locate them and undertake maintenance work. Local residents have been spotted taking bikes home, putting a personal lock on it, selling them either on the black market or even exporting to other countries. Cases in which people would manipulate the system and commit fraud by linking the QR codes to their personal bank accounts have also been reported. This kind of bad behavior does not only damage the reputation of bikesharing companies but also cause immense losses (Hernández, 2017).

Therefore, the Chinese government now requires users to use their real name upon registration and to provide a form of identification. After the fatal death of a 10-year-old child in Shanghai who was killed by a bus while riding a shared bike and many other incidents, the public strongly urged the government to enforce stricter regulations on the bikesharing industry. To protect children and avoid any legal disputes about the legal liability in case minors encounter an accident or get injured, the government also prohibited users below 12 years old (also legal cycling age in China) to create an account or use a shared bike on their own. Many firms have also adopted better safety measures (Ni, 2017).

Rebalancing

Rebalancing is another important aspect of bikesharing that has attracted a lot of research attention. Successful rebalancing operations are not only one of the key success factors of the bikesharing system but also in reducing operating costs and enhancing user experience (Pal & Zhang, 2017). When successfully carried out, rebalancing is also able to reduce the idle time of bicycles and increase system efficiency (Chang, Song, He, & Qiu, 2018).

Since the convenience of dockless bikesharing originates from having bicycles located all across the city, rebalancing is inevitable because the users move the bicycles around from residential to commercial zones and vice versa. It is not unusual that during the morning and evening peak hours (before and after work/school/university) the supply of bikes is insufficient while many bicycles remain unused during the day. Consequently, some locations will be occupied with lots of bicycles while others are completely empty resulting in lower user satisfaction due to the lack of reliability. This imposes tremendous costs on the bikesharing providers.

For this reason, the bicycles need to be manually redistributed throughout the city using specially designed trucks (Pal & Zhang, 2017). On the one hand, rebalancing creates jobs that were not there before but on the other hand, it takes up a great portion of the expenses of bikesharing operators. Besides the "tidal flows", a number of other aspects also influence the usage of bikesharing including the weather conditions (rain, snow, sun and seasons), weekday compared with the weekend, hilliness and urban density (Fishman E. , 2016; Cui, 2018).

Rebalancing is often one of the largest challenges for the bikesharing operator because they have to minimize the financial and environmental costs while trying to serve as many users as possible. Therefore, apart from manually redistributing the bikes, many bikesharing operators also aim to incentivize their users to self-rebalance the bikes by providing reduced usage fees for moving bikes from and to certain locations. This kind of rebalancing with a considerable amount of user intervention is called dynamic rebalancing as opposed to static rebalancing when the bikesharing operator takes full responsibility (Pal & Zhang, 2017).

Operation models of bike sharing systems in China

From a government perspective, public transportation networks and transit services have the purpose of providing accessibility for all citizens. Therefore, they are expected to cover as many areas as possible to ensure geographic equity. As a consequence, most public transit systems would be unprofitable because they do not produce enough income through ticket revenue to cover the operational costs (Buehler & Pucher, 2011).

In an unregulated free market, transit agencies would only focus their expansions in "areas with greatest ridership potential" and unprofitable services in fringe areas would be cut. As analyzed by Reinhold and Kearny (2008), German public transport operators have aimed their attention on routes that are profitable and attractive with lots of users while curtailing their services on less busy routes. However, this comes at the expense of certain groups as the accessibility of low-income residents or car-less households living in remote or isolated locations will be limited.

Thus, most governments still have to heavily subsidize the less profitable public transport to ensure that there is no loss in the quality of life of certain groups (Buehler & Pucher, 2011). This is the main reason why almost all transport companies are state-owned-enterprises (SOEs) in China. Over the years, a number of business models with various degrees of stakeholder involvement and government control have emerged. Stakeholders include but are not limited to the municipality or local government, communities, bikesharing operators, advertising firms and organizations in the private sector (Zhang, Zhang, Duan, & Bryde, 2015).

In China, the most prominent two are the government-run model (GR) and the public-private partnership model (PPP) (Lohry & Yiu, 2015).

Researchers have suggested that operations models which are not-for-profit and subsidized by the local government seem to be the most successful ones. Only these bike providers have the ultimate goal to "reduce environmental impact, lessen traffic congestion, enhance mobile connectivity, and finally improve public health" which are aligned with the objectives of the government (Zhang, Zhang, Duan, & Bryde, 2015).

As Castro explains bikesharing works just like another segment of the public transport network and therefore the city needs to be involved with the planning. If the bikesharing system is not subsidized by the local government, the degree of control the municipality is able to exert on the bike operators is also limited. This could potentially create problems when it comes to expansion plans of bikesharing into residential areas apart from just providing the service in the city center. With less control there is a high risk that it might lead to uncontrolled expansion. Thus, municipalities should subsidize bikesharing schemes as much as possible in order to be able to influence the direction of the bikesharing development in the future (Castro, 2017).

O'Dwyer who is from Urbo, a bikesharing operator in Dublin, holds the same opinion that no subsidies from the local government makes the city lose its control over the bikesharing system. As a result, bikesharing might not benefit as many people as it possibly can due to a profit-maximizing strategy. Therefore, he suggests the city councils to take a higher level of ownership and plan it as a subsidized system with a public perspective rather than taking a Laissez-faire approach and letting the free market do (O'Dwyer, 2017).

On the other hand, for a bikesharing operator to survive in the long-term and have sustainable growth, a suitable market is needed to generate enough profit without having to rely on external funding from venture capitalists or angel investors (Zhang, Zhang, Duan, & Bryde, 2015). One of the largest revenue sources comes from sponsorships as bikesharing is an ideal advertising platform (Friedman, 2017; O'Dwyer, 2017). With sponsorships, the city might only lose control over the "look and feel" of the system but not over the important aspects such as the price scheme, the service quality, the choice of the bikesharing operator or the business model (Friedman, 2017).

Nevertheless, due to the financial incentive structure of the PPP model, conflicts of interests between the private bikesharing company and the government are inevitable. GR models or heavily subsidized bikesharing schemes appear to be more effective than a pure profit-based model. They are not only more successful in terms of their performance measured in ridership, population served and the utilization rate but are also guaranteed to pursue bikesharing as a feasible transport option and public welfare service (Lohry & Yiu, 2015; Wang, Wei, & Tian, 2011). According to Lohry and Yiu (2015), other developing countries could learn valuable lessons from the effective Chinese public service model of bikesharing and consider implementing it as an affordable transport mode in addition to the existing public transit network (Lohry & Yiu, 2015).

To summarize, if there are no government subsidies, support, and control, the area covered by the transportation network would be way less than what would be desirable and many people would experience a loss in quality of life.

III.   Data and Methodology

Case Description of Beijing

What is special about Beijing and makes bikesharing so successful in China?

Because this paper aims to analyze the effect and impact bikesharing has on the reduction of car use and modal shifts in Beijing, it is absolutely necessary to know the unique characteristics of Beijing and what is so different about bikesharing in China that caused the widespread popularity and tremendous expansion.

1) Low labor and production costs
First of all, the labor costs in China are extremely low compared to North America or Europe. Since the labor costs associated with the rebalancing process, maintenance and the production of new bicycles are major cost drivers of bikesharing operations, these costs per bike are relatively low in China. Having this cost advantage, bikesharing operators in China could expand their operations very rapidly to over 200 cities (Yin & Tan, 2017).

2) High population and building density → economies of scale
China has some of the most densely populated cities in the world. A higher population density is strongly linked to better performance of bikesharing systems (Zhao, 2014) because bikesharing operators can benefit from economies of scale (Meddin R. , 2017). Furthermore, urban building density is negatively correlated with the idle time of the shared bicycles but leads to more rebalancing activities (Cui, 2018).

3) Blind spots in public transit network
There is a considerable number of shared bikes placed right next to the metro and bus stations to tackle the "last mile" problem. Although the metro network in Beijing is one of the largest in the world, it is not extensive enough to reach and cover the entire city leaving plenty of "blind spots" (Jacobs, 2018). Bikesharing has the potential of eliminating those blind spots, areas with a radius of 500m which have no connection to public transit, resulting in complete coverage of Beijing with transit nodes (Yin & Tan, 2017).

4) Bicycle kingdom in China
Cycling has a long history in China which was once known as the "bicycle kingdom". Cars have only become popular in China in the last decade and it is fairly normal to use a bicycle as a means of transportation because people have been cycling since their childhood.

5) Severe congestion problem
There is no doubt that Beijing is suffering under severe congestion and pollution problems. Because of that Beijing has been in the headlines countless times and many of China's giant cities are trying to cope with the immense population "chocked by traffic jams and pollution" (Branigan, 2014).

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6) Government support and regulations

Another unique aspect of China is the tremendous government support of the bikesharing industry in various forms such as tax breaks which facilitated the rapid growth of bikesharing. Compared to the US, where it often takes up to years until a request is processed and approved, the regulations were initially relatively loose with respect to bikesharing leading to cluttered sidewalks. But in the US, this is inconceivable since Americans are less tolerant of sidewalks being overcrowded with bicycles (Jacobs, 2018).

7) Ease of online payment through QR code valuable user data

Many of the bikesharing companies have received funding from tech giants such as Alibaba and Tencent which have their own mobile payment apps. Since payment is done by scanning the QR codes, bikesharing usage also increases the use of AliPay and WeChat Pay which own considerable shares of the bikesharing firms. Therefore, bikesharing not only generates a ton of valuable data on the commuting habits of its users but also for the credit scoring services of Tencent and Alibaba.

Survey methodology

A cross-sectional survey with a target population of people who have visited, lived or are currently living in Beijing was conducted. Given the time constraints and the logistical difficulty in conducting intercept or random household surveys in China, data was collected through an online questionnaire with 34 (sub)questions in total. The online questionnaire was created using the Qualtrics Platform and the questions consisted of several different question types including multiple choice, rank order, matrix table and slider which lets respondents indicate their level of preference with an adjustable bar.

Furthermore, display logic was used to create a survey that can dynamically adapt to each respondents' answers and is customized to them. This is because some questions are not relevant to all respondents depending on how they have answered previous questions such as whether they have used dockless bikesharing before or not. Last but not least variable names and the recode values of some questions were adjusted and some categories that did not have a sufficient number of responses such as "Doctorate" in highest education level attained were merged with others.

To reach a sample size which is somewhat representative of my target population and sufficient for the analysis, the aim was to collect a minimum of 100 responses. The online survey was distributed through multiple social media channels including Facebook (groups) and WeChat and was conducted from August 7th, 2018 to August 23rd, 2018. In total there were 208 survey responses out of which 126 were completed and 97 partially completed.

Descriptive Statistics

Due to many partially completed responses, the sample size differs for each of the questions. For illustration purposes, certain categories such as "other" or "no car" have been removed from the charts. It is also important to note that due to the chosen distribution method for the survey, all respondents must have access to the internet and use one of the mentioned social media channels.

Sample Demographics

The demographic characteristics of the sample were used to identify any differences in bikesharing usage and modal shift rates. Table 1 shows the profile of the sample (including gender, age, highest education level attained, current occupation status and the continent of origin if the respondents are not from China), with a total of 126 observations. Since the questions about the respondents' demographics were at the very end of the survey, the data only consists of respondents that have completed the entire survey.

Due to the fact that 67.46 % of my respondents were female and 32.54% were male, weights were added to avoid the collected results to be skewed in favor of the women's answers. Adding weights to the responses also helps to represent the target demographic more accurately assuming the proportion of users to consist of an equal distribution of male and female users.

The age distribution shows that 48.41 % of the respondents were between 18 and 24 years old which is related to the rather high percentage of students (52.38 %) and respondents having a bachelor's degree (44.44 %) in the sample. Looking at the country/continent of origin, the sample is relatively balanced with around 60 % of the respondents from China and 40 % from all over the world out of which Europe (22.22%) represents the largest non-Chinese group.

Table 1 Demographic Variables of Respondents

Category	Percentages	Number of Respondents
Gender	**%**	**N = 126**
Male	32.54 %	41
Female	67.46 %	85
Age	**%**	**N = 126**
18-24	48.41%	61
25-34	24.60%	31
35- 44	7.14%	9
45 - 54	9.52%	12
55 - 65	10.32%	13
Highest Education Level	**%**	**N = 126**
High School	11.11%	14
Some College	15.08%	19
Bachelor's Degree	44.44%	56
Graduate Degree	29.37%	37
Occupation Status	**%**	**N = 126**
Student	52.38%	66
Employed	30.16%	38
Unemployed	5.56%	7
Retired	11.90%	15
Country/Continent of Origin	**%**	**N = 126**
China	59.52%	75

Europe	22.22%	28
North America	5.56%	7
South America	2.38%	3
Africa	0.00%	0
Asia (not Chinese)	9.52%	12
Oceania	0.79%	1

Cross-Tabulation Analysis

To make statistical inferences about the population being studied and to analyze whether a significant relationship between two variables exists, cross-tabulations were carried out. The chi-square test statistic is calculated using the observed and expected values and was thereby used to check the statistical significance of the cross-tabulation tables and whether they are independent of each other.

A significance level of 5% was chosen and if the p-value of the test is higher than 0.05, the results would be insignificant, and we are cannot reject the null hypothesis, meaning that we assume there is no relationship between the variables. In case the results are statistically significant, and the null hypothesis is rejected, then it means that it is highly likely there is a relationship between the variables and they are somewhat related.

H0: There is no association between the two tested categorical variables
H1: There is an association between the two tested categorical variables

IV.   Results

First of all, it is assumed that all of the respondents have access to a bikesharing system and that there are a sufficient number of shared bikes close the residential area and places people need to travel to. Thus, not using a shared bike is a choice the respondent has made and not because bikesharing is unavailable. In addition, it is assumed that not knowing how to cycle is not one of the reasons why people refrain from the use of bikesharing.

79% of my respondents have used dockless bikesharing before and those who have no prior experience were only displayed relevant questions such as reasons why they are not using a shared bike.
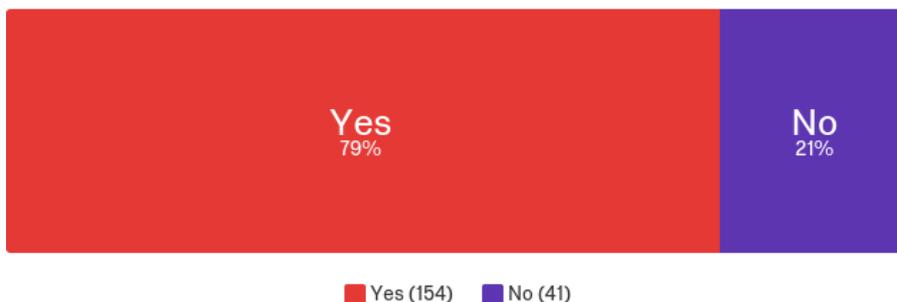
Have you ever used a dockless bike before?

Yes (154)   No (41)

Figure 7 Usage of Dockless Bikes in Percentage

Almost half of the respondents who have used dockless bikesharing before are registered at more than two different bikesharing operators and 4% has even between 3-5 different accounts. This might be due to the fact that the required deposit to join a bikesharing system is relatively low and people want to avoid scenarios where they are unable to find a bike. It is also striking that almost 9% do not have a bikesharing account although they have used a shared bike before. These users could be classified as "one-time" users that might have been traveling with friends or gained access to a shared bike through someone else's account.

Q3 - From how many different bikesharing operators do you have an account?
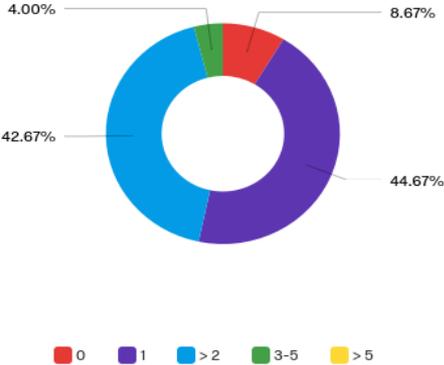
Figure 8 Number of Bikesharing Accounts Respondents Have in Percentage

Figure 9 illustrates the motivating factors for using bikesharing. As previously highlighted, dockless bikesharing provides more flexibility and convenience (92.39%) to its users which is also the predominant motivations for its use followed by environmental benefits (34.78%). Proximity to the university campus (31.52%) is the third strongest reason followed by "avoidance of congestion", "financial savings over public transport", "health benefits" and "proximity to public transport stations" which all have been chosen about 20% of the times.

What mainly motivated you to become a bikesharing user?

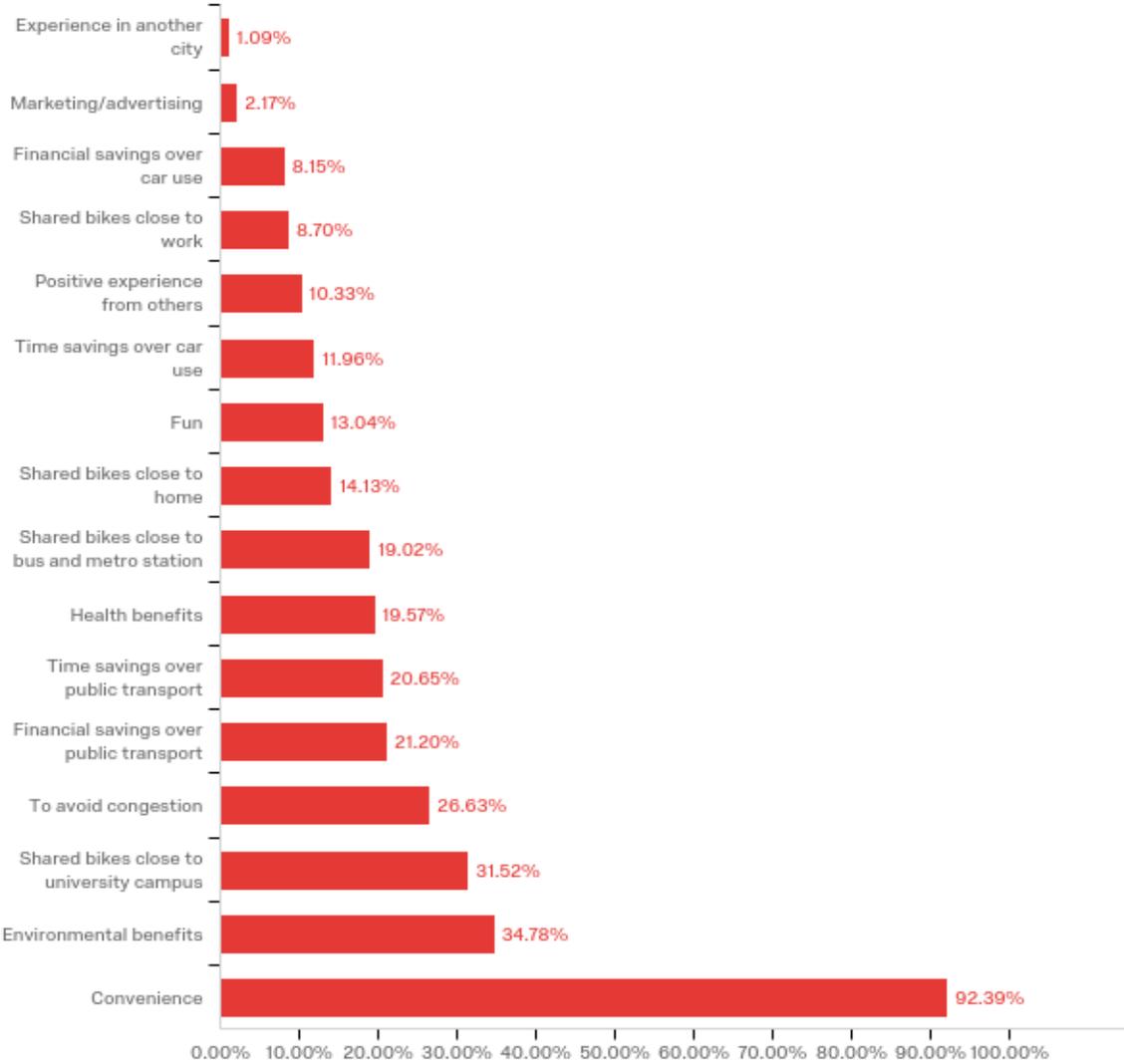|	
Experience in another city	1.09%
Marketing/advertising	2.17%
Financial savings over car use	8.15%
Shared bikes close to work	8.70%
Positive experience from others	10.33%
Time savings over car use	11.96%
Fun	13.04%
Shared bikes close to home	14.13%
Shared bikes close to bus and metro station	19.02%
Health benefits	19.57%
Time savings over public transport	20.65%
Financial savings over public transport	21.20%
To avoid congestion	26.63%
Shared bikes close to university campus	31.52%
Environmental benefits	34.78%
Convenience	92.39%

Figure 9 Motivating Factors of Becoming Bikesharing Users

The major barrier to bikesharing for this sample was safety concerns due to the traffic (Figure 10). This corresponds to the low average satisfaction (satisfaction score of 59.1) with the cycling lanes in Beijing (Appendix Figure 2). The other major barriers were sign-up problems such as respondents finding the process being too complicated, unclear or time consuming. This is followed by the public transit services, private bike or driving being more convenient for the respondents. Despite the constant headlines of smog and air pollution in Beijing, only 11.76 % have indicated it as a reason for not using bikesharing.

Why are you not using a shared bike?

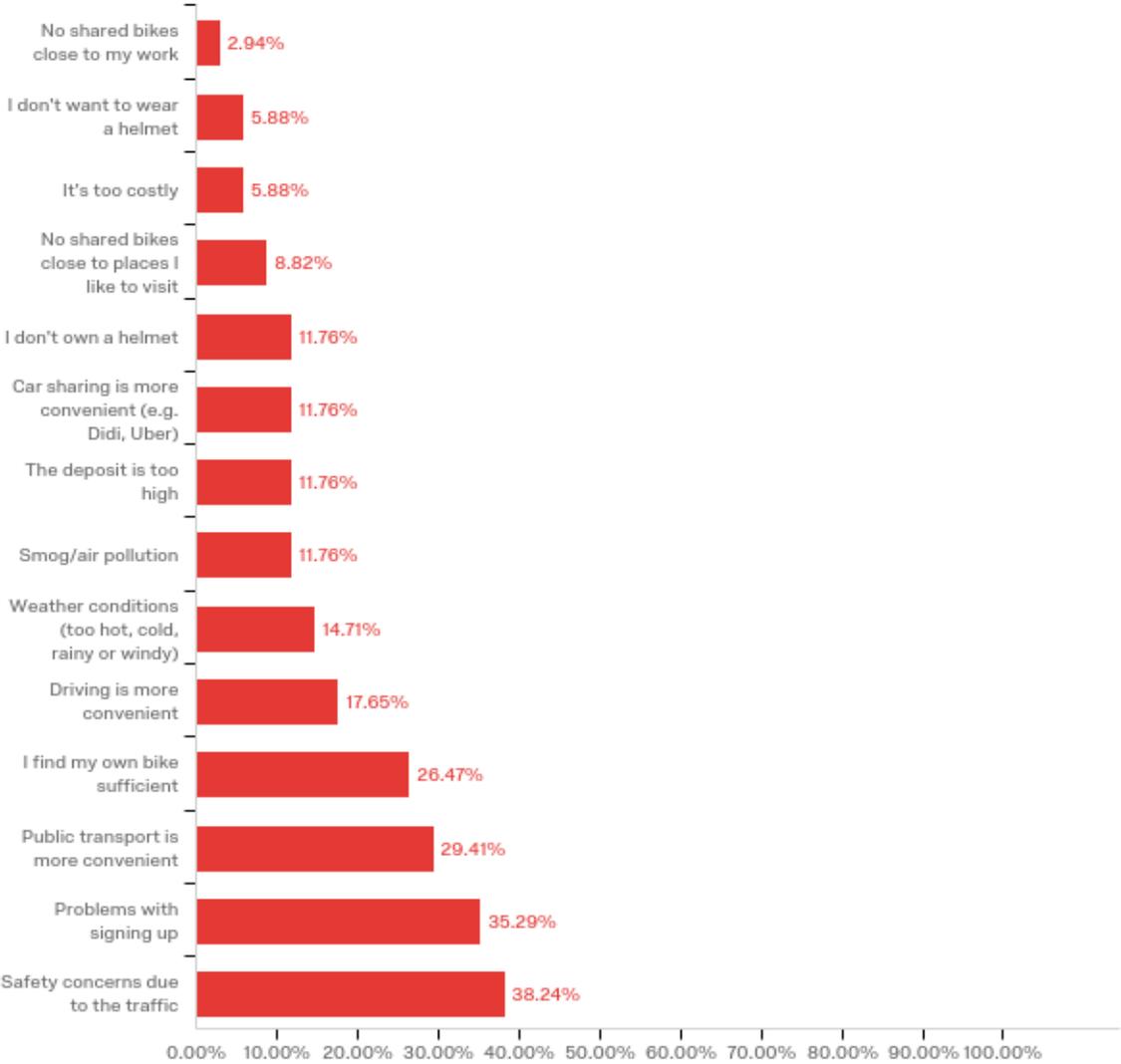| Reason	Percentage
No shared bikes close to my work	2.94%
I don't want to wear a helmet	5.88%
It's too costly	5.88%
No shared bikes close to places I like to visit	8.82%
I don't own a helmet	11.76%
Car sharing is more convenient (e.g. Didi, Uber)	11.76%
The deposit is too high	11.76%
Smog/air pollution	11.76%
Weather conditions (too hot, cold, rainy or windy)	14.71%
Driving is more convenient	17.65%
I find my own bike sufficient	26.47%
Public transport is more convenient	29.41%
Problems with signing up	35.29%
Safety concerns due to the traffic	38.24%

Figure 10 Reasons for not Using Bikesharing

When asked whether any of the respondents ever had technical problems with a shared bike such as being unable to continue or even start their journey due to parts being broken, roughly 87% reported to having a friend/colleague/family member or themselves experiencing this inconvenience (Appendix Figure 3).

As previously identified, the safety concerns due to traffic were the dominant reason why people choose not to use bikesharing. This is also reflected in two other questions namely how safe respondents feel when sharing the same road with a cyclist while driving a car and when riding a shared bike on the road themselves. Findings show that "Somewhat unsafe" was chosen the most in both questions with 35.71 % and 44.55 % (Appendix, Figure 4 and 5) respectively which corresponds with previous study that have found providing separate bicycle infrastructure and well-maintained cycling lanes such as keeping them clear of ice and snow reduces seasonal fluctuations in usage increases perceived safety (Gebhart & Noland, 2014; Liu, Jia, & Cheng, 2012).

Figure 11 shows the usage frequency of bikesharing. It is relatively evenly distributed with roughly 25 % who use it every second day, 24% who use it only 1-3 times per month and 22 % who use it fairly frequently between 5 and 10 times per month. More than 26% of the respondents also use it at least 21 times per month, thereof more than 13 % even daily.

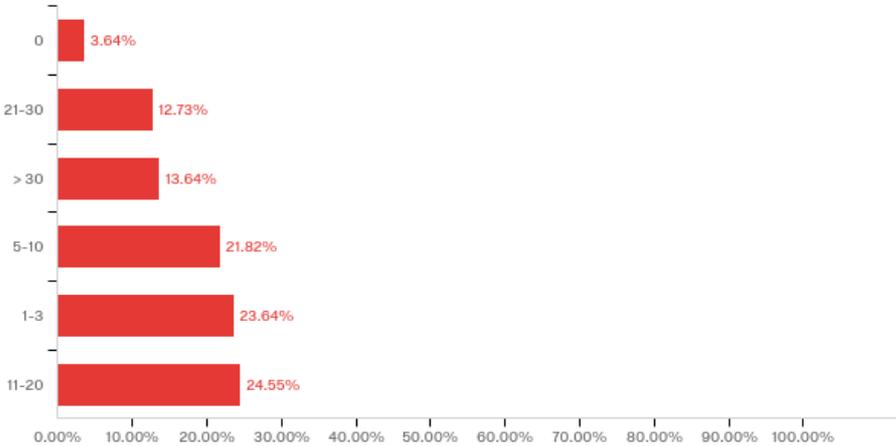How many times do you use bikesharing on average per month?

Figure 11 Number of Times Respondents Use Bikesharing on Average per Month

Most people (86.36 %) use bikesharing predominantly throughout the whole week (Appendix, Figure 6) and for short trips lasting less than 30 mins. Only about 14 % of the people use it for more than 30 mins (Appendix, Figure 7).

Among the aspects of dockless bikesharing systems that need the most improvements are that respondents think there are too many broken/unusable bikes, they cannot find a bike when needed and cluttered sidewalks (Appendix, Table 1). This correlates to the previous data that many people have encountered technical problems of shared bikes highlighting their poor quality and inexpensive design.

Bikesharing is used for many purposes, ranging from commuting to work/school/university to leisure activities such as going shopping or sightseeing. The main purpose, however, is related to the convenience aspect of dockless bikesharing namely getting to a public transit node (20.94%) followed by getting around on campus (due to a large proportion of respondents being students; 18.05 %) and commuting purposes (27.80 %).
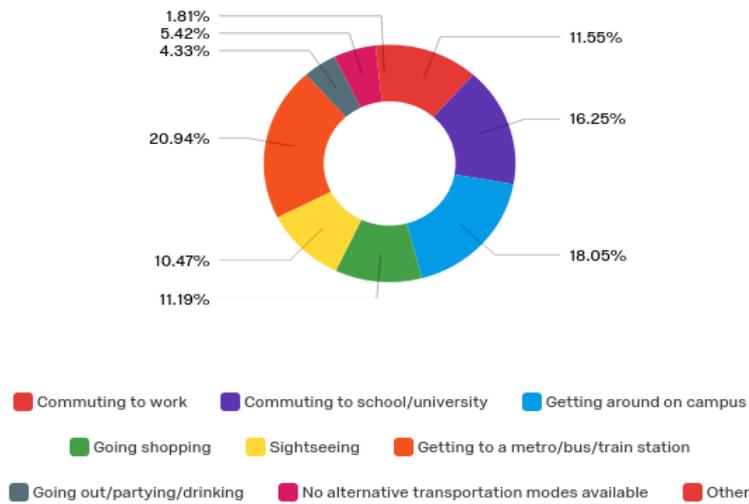
What is the purpose of your trip?

Figure 12 Purpose of Bikesharing Trip

Despite all the negative elements to bikesharing, more than 83% of my sample would agree or strongly agree that bikesharing is an enhancement to the public transportation system in Beijing (Appendix, Figure 8).

To answer the central research question regarding the reduction in car use and analyze the modal shift impacts due to bikesharing, several questions were created to capture the percentage of people that actually switched away from the car.

As explained earlier, many researchers have claimed that bike sharing facilitates multimodal transport and acts as a complement rather than a substitute for public transportation. To verify this, respondents were asked how often they have replaced car trips with trips made with public transit and bikesharing. 20 % and 13.64 % of the respondents have replaced car trips with a combination of bikesharing and public transport services most of the time or about half the time respectively. More than 45 % answered that they sometimes prefer to use bikesharing and public transit together instead of traveling by car and 6.36 % have completely shifted away from using the car since joining bikesharing.

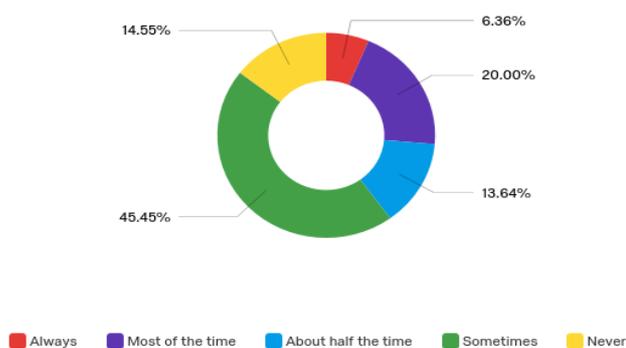I have replaced trips by car with trips made with public transit and bikesharing.

Figure 13 Frequency of Using Bikesharing and Public Transit Together Instead of the Car in Percentage

When asked whether there are any mobility changes and in what way the respondents' travel behavior changed as a result of their bikesharing usage, the results have confirmed the positive effects of bikesharing. Almost 70% reported to be riding a bicycle more or even much more often due to using bikesharing and around 52% stated their shopping frequency at locations near existing shared bikes have increased. Around 20% now drive a car (much) less often than before joining bikesharing and bikesharing's impact on the reduction of the taxi and car sharing usage is even more prominent. Roughly 54% of respondents stated they use a taxi or car sharing services (much) less often compared to without bikesharing.

As illustrated before, bikesharing is often seen as an effective solution to solving the "first and last mile" problem because it serves as a way of eliminating the "blind spots" in the public transportation network and helps to overcome the short distance between the residence/work and the closest public transit station. About 69% of the time bikesharing is now used for distances that people used to walk which can be seen in Figure 14.

The concern might exist of whether the physical activity of people has decreased as a result of bikesharing. However, this is not the case, since those people that walk less often now are probably also those that have indicated to be cycling more often. Furthermore, almost 30% have even reported walking more often than before which could be due to the fact that they engage in more leisure activities such as shopping at locations that were inaccessible before.

Last but not least, roughly 27%, 9%, and 22% have reported no changes in the use of public transportation, car, and taxi or car sharing services respectively. This means that all the bikesharing trips taken by those respondents who did not change their commuting behavior much with the aforementioned travel modes are most likely new trips. These new trips do not necessarily contribute to a reduction in GHGs but are probably increasing the accessibility to certain locations of some groups and enhancing their life quality.

Therefore, apart from the obvious environmental benefits due to a reduction in usage of motorized vehicles, bikesharing also contains significant health and socioeconomic benefits. A large proportion of my sample cycles and walks more than before and due to the existence of shared bikes, shops and restaurants also profit from a higher number of customers resulting in a GDP boost and economic growth.
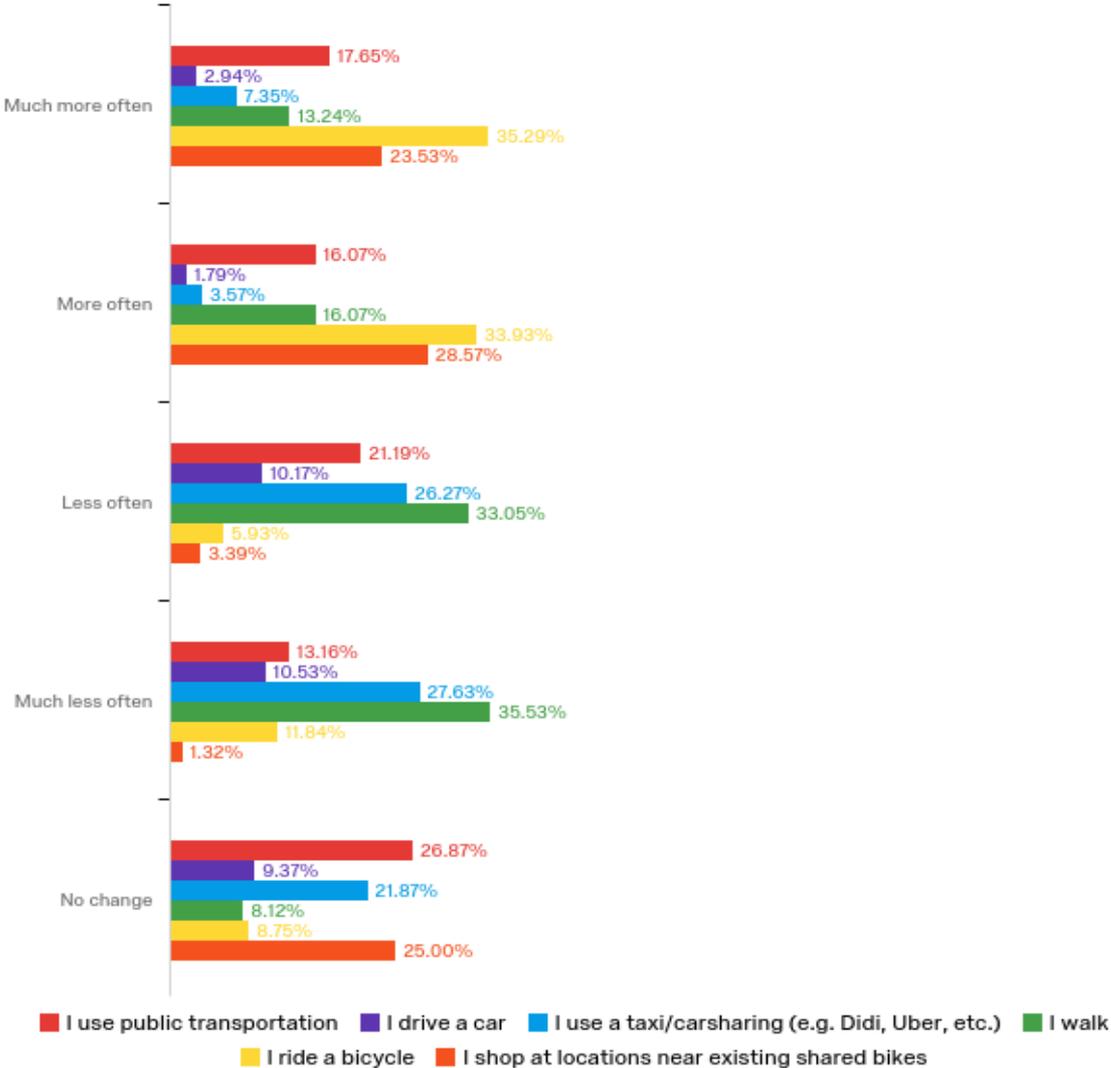
Because I use bikesharing,

Figure 14 Change in Mobility Behavior as a Result of Bikesharing Usage in Percentage

Cross-Tabulation Results

From the results in Table 2, 3, 4 it is evident that there is a significant relationship between both the age and the occupation status of the respondents and whether or not they have used dockless bikesharing in Beijing. Not surprisingly, the occupation status and age profile reflect a similar trend in the usage of dockless bikesharing which might be because there is a significant relationship between age and occupation status itself (Appendix XXX). About 95% of the students and employed have used dockless bikesharing before compared with only 29% and 60% of the unemployed and retired. With respect to age, it appears that the oldest age group has the least experience with bikesharing and people between 35 and 44 years old use bikesharing disproportionately less. The first might be due to less familiarity with smart technology as many have reported too complicated and time-consuming sign-up process of bikesharing to be one of the major barriers. However, the sample size of these two groups are relatively small and there is insufficient data about people that do not use bikesharing, therefore they might not provide an accurate representation.

Table 2 Cross-Tabulation of Occupation Status and Usage of Dockless Bikesharing and Age and Dockless Bikesharing

		Have you ever used a dockless bike (e.g. Ofo, Mobike, etc.)? A dockless bike is a bike that you c...		
		Yes	No	Total
What is your occupation status?	Student	63 95.45%	3 4.55%	66 100.00%
	Employed	36 94.74%	2 5.26%	38 100.00%
	Unemployed	2 28.57%	5 71.43%	7 100.00%
	Retired	9 60.00%	6 40.00%	15 100.00%
	Total	110 87.30%	16 12.70%	126 100.00%
How old are you?	18-24	58 95.08%	3 4.92%	61 100.00%
	25 - 34	28 90.32%	3 9.68%	31 100.00%
	35 - 44	6 66.67%	3 33.33%	9 100.00%
	45 - 54	11 91.67%	1 8.33%	12 100.00%
	55 - 65	7 53.85%	6 46.15%	13 100.00%
	Total	110 87.30%	16 12.70%	126 100.00%

Table 3 Chi-Squared Test Between Age and Usage of Dockless Bikesharing

		Have you ever used a dockless bike (e.g. Ofo, Mobike, etc.)? A dockless bike is a bike that you c...
How old are you?	Chi Square	20.37*
	Degrees of Freedom	4
	p-value	0.00

Note: The Chi-Square approximation may be inaccurate - expected frequency less than 5.

Table 4 Chi-Squared Test Between Occupation Status and Usage of Dockless Bikesharing

		Have you ever used a dockless bike (e.g. Ofo, Mobike, etc.)? A dockless bike is a bike that you c...
What is your occupation status?	Chi Square	37.72*
	Degrees of Freedom	3
	p-value	0.00

Note: The Chi-Square approximation may be inaccurate - expected frequency less than 5.

Furthermore "age" also has a significant relationship with attitudes on Beijing cycling conditions as well as environmental issues, the frequency of bikesharing usage and modal shifts (Appendix, Table 5 and Appendix, Table 6). There are significant differences in different age groups concerning those aspects. However, age is not significantly associated with the motivation of becoming a bikesharing user (Appendix, Table 7). Younger people (18 – 24) appear to find health benefits of bikesharing, avoiding congestions less important and the fact that there are shared bikes close to the university campus and time savings over public transport more important compared to the average (Appendix, Table 8).

Contrary to my initial expectations, the car reduction rate due to bikesharing and degree to which people shift away from using the private car or car sharing services are independent of both the trip purpose and respondents' motivation of using bikesharing (Appendix, Table 9 and Appendix, Table 10). Therefore, whether people use bikesharing as a means of commuting or for recreational activities does not affect how much people drive a car significantly. Furthermore, whether people use bikesharing due to environmental or convenience reasons is also not significantly associated with the car reduction rate.

Looking at the significant relationship between age and education level in Table 5 and 6, these two variables are most likely related to each other and confirm an important fact that China has undergone a tremendous transition in its education system. Over the last two decades, younger people have received more access to higher education. Thus, the younger generation has enjoyed more years of schooling and are relatively more educated compared to the older age group leading to a substantial generational gap in education. This might also affect the willingness to use dockless bikesharing and attitudes towards the environment.

Table 5 Cross-Tabulation of Age and Education Level

		What is your highest education level attained?						
		Less than high school	High school	Bachelor's degree	Graduate degree	Doctorate	Some college	Total
How old are you?	Under 18	0 0.00%	1 100.00%	0 0.00%	0 0.00%	0 0.00%	0 0.00%	1 100.00%
	18-24	0 0.00%	3 5.00%	36 60.00%	13 21.67%	0 0.00%	8 13.33%	60 100.00%
	25 - 34	0 0.00%	0 0.00%	9 29.03%	19 61.29%	2 6.45%	1 3.23%	31 100.00%
	35 - 44	0 0.00%	3 33.33%	2 22.22%	2 22.22%	1 11.11%	1 11.11%	9 100.00%
	45 - 54	0 0.00%	6 50.00%	3 25.00%	0 0.00%	0 0.00%	3 25.00%	12 100.00%
	55 - 64	0 0.00%	1 8.33%	6 50.00%	0 0.00%	0 0.00%	5 41.67%	12 100.00%
	65 or older	0 0.00%	0 0.00%	0 0.00%	0 0.00%	0 0.00%	1 100.00%	1 100.00%
	Total	0 0.00%	14 11.11%	56 44.44%	34 26.98%	3 2.38%	19 15.08%	126 100.00%

Table 6 Chi-Square Test of Age and Education Level

		What is your highest education level attained?
How old are you?	Chi Square	83.79*
	Degrees of Freedom	30
	p-value	0.00

Note: The Chi-Square approximation may be inaccurate - expected frequency less than 5.

## V.	Discussion and conclusion

Given the data collection method and the fact that the case study is based on a survey, there are certain study limitations that need to be addressed. With any survey, there are a number of biases which could influence the outcome, validity, and reliability of the study especially when a random sample could not be drawn. Self-selection is thereby often an issue since the respondents voluntarily agreed to participate in the survey. Because the respondents have certain traits and characteristics which can be systematically different from the target population, the results are less representative.

As the aim of this paper is to understand the modal shift impacts of bikesharing and in what way it can change people's mobility behavior, a longitudinal study would have been more appropriate in recording the respondents' changes in their attitudes and travel behaviors over a period of time. Moreover, conducting a random household or intercept survey could possibly reduce the bias. However, these options were not feasible due to the scope and restricted time of this study. Hence, the results are solely based on the respondents' self-reported attitudes and behavior. As mentioned before, response weighting has been applied to obtain results that are more representative of the target population's demographics.

In answering the proposed research question to what extent bikesharing reduces car use we find that bikesharing in combination with public transport indeed replaces at least some of the car trips in more than 85% of the cases in the sample. One out of five respondents now drive a car less frequently and more than half use taxi or car sharing services less often as a result of using bikesharing. Apart from the immense environmental benefits, the results also confirm huge health and socioeconomic benefits due to more physical exercise and increased accessibility. These benefits can possibly lead to lower public health spending and reduce geographical inequity for the whole society

Despite the study limitations, the survey results provide us with preliminary insights into the modal shift impacts of bikesharing in Beijing. However, these results might not necessarily be able to represent other Chinese cities let alone other countries. For locations with similar characteristics, notwithstanding, the survey can provide researchers with ideas for what to investigate and improve in future studies. There are still many aspects of dockless bikesharing that have not included in this paper or been addressed in sufficient detail. Further recommendations for future studies include using big data approaches to improve rebalancing efficiency, analyzing the success factors of bikesharing systems and conducting a comparative

study on (Chinese) cities with different characteristics as well as establishing better metrics that measure the modal shift impacts and success of and GHGs reduction due to bikesharing.

Overall, the are many lessons that can be learned from the dockless bikesharing system in China. The system in Beijing serves as a valuable example for other high-density cities that consider implementing dockless bikesharing as an integration and extension to the existing public transport network.

The fourth generation of bikesharing would not exist in today's form without the internet and recent advancements in smart technology. Dockless bikesharing systems are a step forward into the future. With its gathered data from millions of shared bikes, it can not only identify "blind spots in public transportation networks" and solve the "first and last mile problem" but also has the potential to completely transform how cities are built and designed. By providing an affordable, accessible and most notably a sustainable and convenient way of transportation, it is an attractive alternative to the private car

Even though bikesharing is facing many problems and challenges, the system has been constantly improving as seen from the developments over the last four bikesharing generations until now. Our society is thriving to reach the same goal of creating environmental awareness and fostering a culture of living in a more sustainable way. In conclusion, the benefits of bikesharing definitely outweigh the negative aspects and can improve the living quality of many people. Therefore, I believe bikesharing will an essential component in revolutionizing the way we travel and keep reinventing itself like in the past.

VI.   Appendix

Public Use Bicycle Programs
by Continent, year end 2016

North America
121

Europe
524

Asia
502

South America
34

Africa
1

Oceania
6
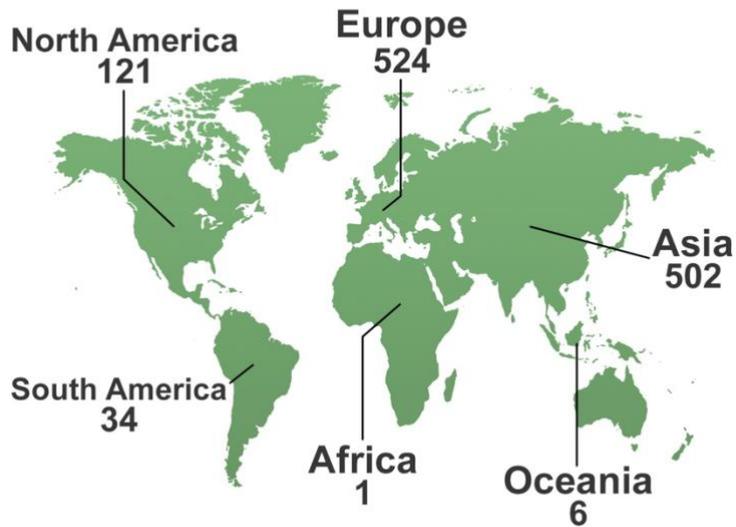
@BikesharingMap
www.bikesharingmap.com
Data collected and maintained by Russell Meddin

Figure 1 Number of Public Use Bicycle Programs by Continent, 2016
Source: Meddin (2016)

How satisfied are you with the cycling lanes in Beijing?

59.1

0   100
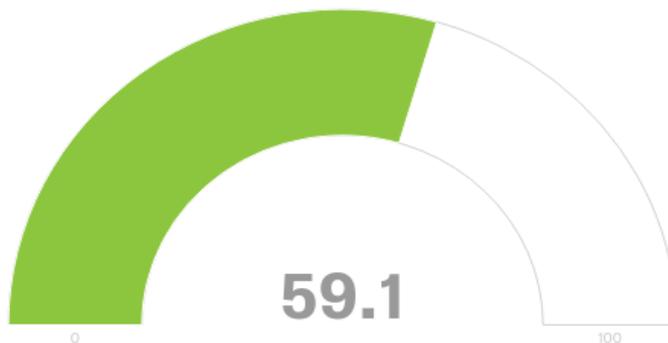
Figure 2 Average Satisfaction Score of Cycling Lanes in Beijing

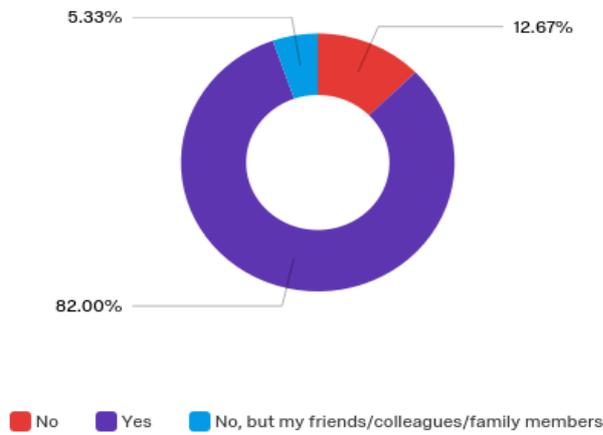Have you ever had any problems with a shared bike?

Figure 3 Technical Problems with a Shared Bike in Percentage

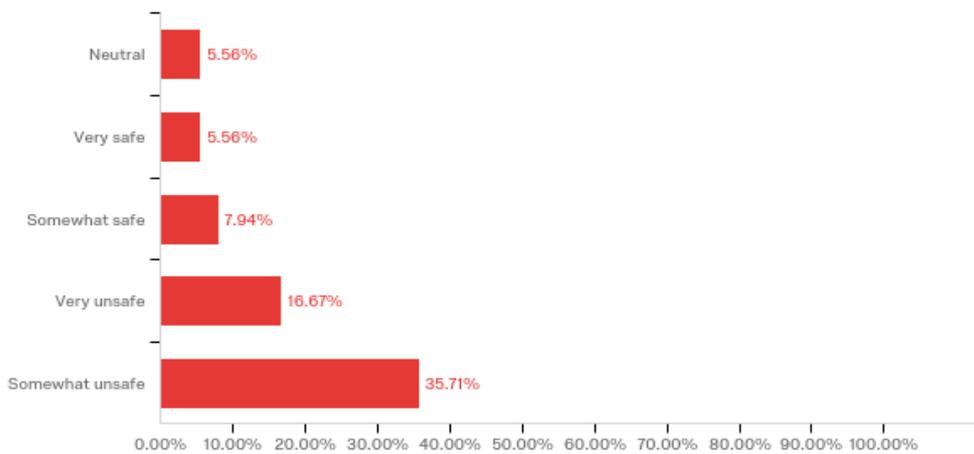How do you feel when sharing the same road with a cyclist as a driver?

Figure 4 How Respondents Feel When Sharing the Same Road with a Cyclist While Driving in Percentage

Q9 - How would you feel when riding a shared bike on the road yourself?
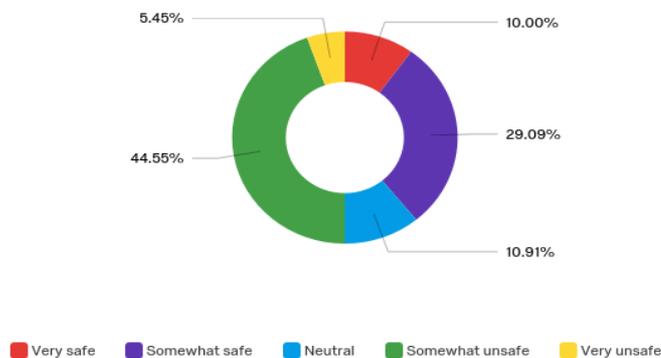

Figure 5 How Respondents Feel When Riding a Shared Bike on the Road Themselves

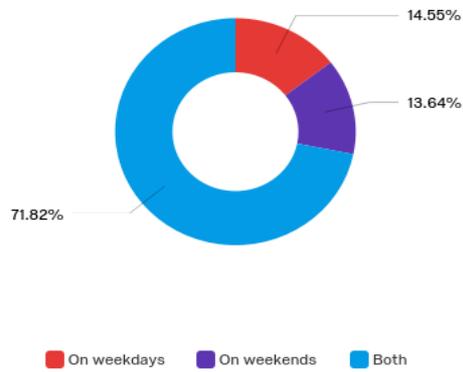Q19 - When do you usually use a shared bike?

Figure 6 Weekend and Weekday Bikesharing Usage in Percentage

Q14 - How much time did you spend on riding a shared bike each time (on average)?
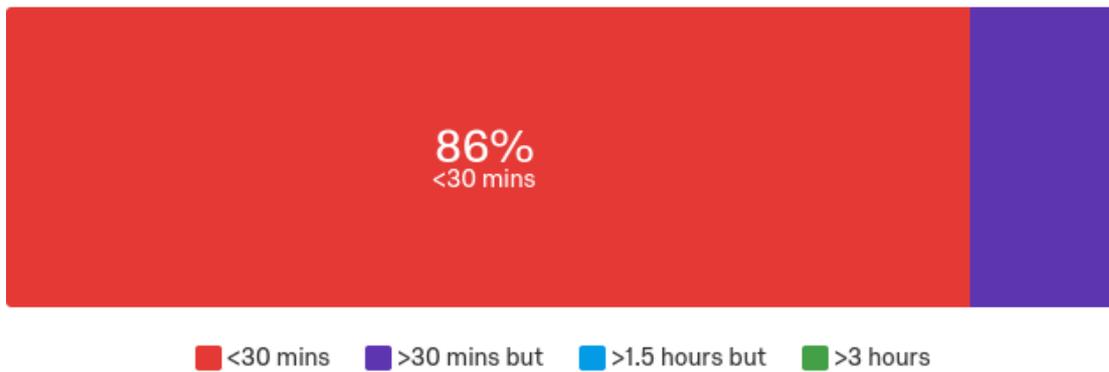

Figure 7 Average Time Spend Using Bikesharing Per Ride

Table 1 Ranking of Aspects of Bikesharing That Need to Be Improved Ranging from 1 to 9

#	Field	Minimum	Maximum	Mean	Count
1	Too many broken/unusable bikes	1.00	8.50	2.80	123
2	Cannot find a bike when needed	1.00	8.50	3.39	123
3	Bikes are overcrowding/cluttering the sidewalks and roads	1.00	8.00	3.53	125
4	There are not enough designated parking areas for the bikes	1.00	8.00	3.98	123
5	There are too many different bikesharing companies/operators	1.50	8.00	5.07	121
6	Insufficient government control	1.50	9.00	5.57	121
7	Simplify sign-up process	1.00	9.00	5.83	124
8	Unsuitable infrastructure for cycling	1.00	9.00	5.70	124
9	Other	1.00	9.00	8.45	106

Bikesharing is an enhancement to the public transportation system in Beijing.
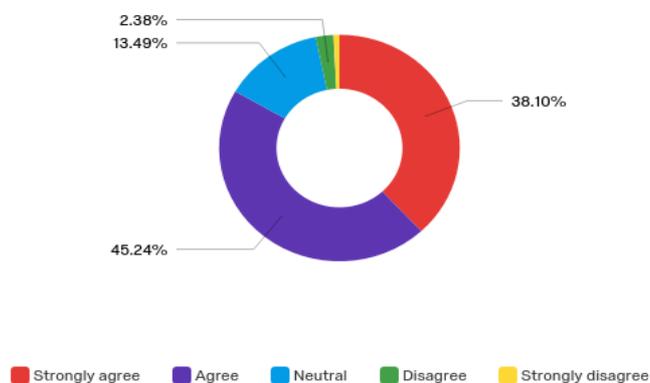
Figure 8 Attitude Towards the Statement That "Bikesharing is an enhancement to the public transportation system in Beijing"

Table 2 Cross-Tabulation of Age and Occupation Status

How old are you?	What is your occupation status?	Student	Employed	Unemployed	Retired	Total
	18 - 24	57 93.44%	2 3.28%	2 3.28%	0 0.00%	61 100.00%
	25 - 34	9 29.03%	20 64.52%	2 6.45%	0 0.00%	31 100.00%
	35 - 44	0 0.00%	7 77.78%	2 22.22%	0 0.00%	9 100.00%
	45 - 54	0 0.00%	6 50.00%	0 0.00%	6 50.00%	12 100.00%
	55 - 65	0 0.00%	3 23.08%	1 7.69%	9 69.23%	13 100.00%
	Total	66 52.38%	38 30.16%	7 5.56%	15 11.90%	126 100.00%

Table 3 Chi-Square Test of Age and Occupation Status

How old are you?		What is your occupation status?
	Chi Square	144.39*
	Degrees of Freedom	12
	p-value	0.00

*Note: The Chi-Square approximation may be inaccurate - expected frequency less than 5.

Table 4 Chi-Square Test of Age and Attitudes Towards Cycling Conditions in Beijing and the Environment and Usage of Dockless Bikesharing

		Have you ever used a dockless bike (e.g. Ofo, Mobike, etc.)? A dockless bike is a bike that you c...	Attitudes on Beijing Cycling Conditions and Environmental Issues - The price of public transit is expensive	Attitudes on Beijing Cycling Conditions and Environmental Issues - Waiting time for public transit is often long	How many times did you use bike sharing in one month (when you were in China)?	As a result of my use of bikesharing, - I use a taxi/carsharing (e.g. Didi, Uber, etc.)	As a result of my use of bikesharing, - I walk	As a result of my use of bikesharing, - I drive a car	What is the purpose of your trip? Please choose max. 3 answers.
How old are you?	Chi Square	20.37*	31.82*	28.34*	35.84*	27.02*	33.87*	36.02*	90.30*
	Degrees of Freedom	4	16	16	20	16	16	16	32
	p-value	0.00	0.01	0.03	0.02	0.04	0.01	0.00	0.00

*Note: The Chi-Square approximation may be inaccurate - expected frequency less than 5.

Table 5 Cross-Tabulation of Age and Modal Shifts and Attitudes on Beijing Cycling Conditions and Environmental Issues

How old are you?	Have you ever used a dockless bike (e.g. Ofo, Mobike, etc.)? A dockless bike is a bike that you c...			Attitudes on Beijing Cycling Conditions and Environmental Issues - The price of public transit is expensive						Attitudes on Beijing Cycling Conditions and Environmental Issues - Waiting time for public transit is often long						How many times did you use bike sharing in one month (when you were in China)?							As a result of my use of bikesharing, - I use a taxi/carsharing (e.g. Didi, Uber, etc.)					
	Yes	No	Total	Strongly agree	Agree	Neutral	Disagree	Strongly disagree	Total	Strongly agree	Agree	Neutral	Disagree	Strongly disagree	Total	1-3	5-10	11-20	21-30	more than 30	0	Total	Much more often	More often	Less often	Much less often	No change as a result of use of bikesharing	Total
18-24	58 95.08%	3 4.92%	61 100.00%	1 1.64%	4 6.56%	14 22.95%	28 45.90%	14 22.95%	61 100.00%	6 9.84%	15 24.59%	15 24.59%	23 37.70%	2 3.28%	61 100.00%	11 18.97%	12 20.69%	14 24.14%	9 15.52%	10 17.24%	2 3.45%	58 100.00%	0 0.00%	2 3.77%	21 39.62%	10 18.87%	20 37.74%	53 100.00%
25-34	28 90.32%	3 9.68%	31 100.00%	0 0.00%	3 9.68%	9 29.03%	13 41.94%	6 19.35%	31 100.00%	12 38.71%	4 12.90%	11 35.48%	4 12.90%	0 0.00%	31 100.00%	2 7.14%	7 25.00%	10 35.71%	4 14.29%	5 17.86%	0 0.00%	28 100.00%	2 7.69%	1 3.85%	5 19.23%	8 30.77%	10 38.46%	26 100.00%
35-44	6 66.67%	3 33.33%	9 100.00%	0 0.00%	3 33.33%	4 44.44%	1 11.11%	1 11.11%	9 100.00%	3 33.33%	2 22.22%	4 44.44%	0 0.00%	0 0.00%	9 100.00%	5 83.33%	0 0.00%	0 0.00%	0 0.00%	0 0.00%	1 16.67%	6 100.00%	0 0.00%	0 0.00%	1 25.00%	0 0.00%	3 75.00%	4 100.00%
45-54	11 91.67%	1 8.33%	12 100.00%	2 16.67%	1 8.33%	4 33.33%	3 25.00%	2 16.67%	12 100.00%	3 25.00%	3 25.00%	6 50.00%	0 0.00%	0 0.00%	12 100.00%	4 36.36%	2 18.18%	3 27.27%	1 9.09%	0 0.00%	1 9.09%	11 100.00%	1 14.29%	1 14.29%	2 28.57%	3 42.86%	0 0.00%	7 100.00%
55-65	7 53.85%	6 46.15%	13 100.00%	3 23.08%	0 0.00%	4 30.77%	6 46.15%	0 0.00%	13 100.00%	3 23.08%	3 23.08%	4 30.77%	2 15.38%	1 7.69%	13 100.00%	4 57.14%	3 42.86%	0 0.00%	0 0.00%	0 0.00%	0 0.00%	7 100.00%	2 33.33%	0 0.00%	2 33.33%	0 0.00%	2 33.33%	6 100.00%
Total	110 87.30%	16 12.70%	126 100.00%	6 4.76%	11 8.73%	35 27.78%	51 40.48%	23 18.25%	126 100.00%	27 21.43%	27 21.43%	40 31.75%	29 23.02%	3 2.38%	126 100.00%	26 23.64%	24 21.82%	27 24.55%	14 12.73%	15 13.64%	4 3.64%	110 100.00%	5 5.21%	4 4.17%	31 32.29%	21 21.88%	35 36.46%	96 100.00%

Table 6 Cross-Tabulation of Age and Modal Shifts and Trip Purpose

How old are you?	As a result of my use of bikesharing, - I walk						As a result of my use of bikesharing, - I drive a car						What is the purpose of your trip? Please choose max. 3 answers.									
	Much more often	More often	Less often	Much less often	No change as a result of use of bikesharing	Total	Much more often	More often	Less often	Much less often	No change as a result of use of bikesharing	Total	Commuting to work	Commuting to school/university	Getting around on campus	Going shopping	Sightseeing	Getting to a metro/bus/train station	Other	Getting around after going out/partying/drinking	There are no other alternative transportation modes available	Total
18-24	2 3.45%	8 13.79%	27 46.55%	14 24.14%	7 12.07%	58 100.00%	0 0.00%	0 0.00%	6 40.00%	3 20.00%	6 40.00%	15 100.00%	8 13.79%	37 63.79%	40 68.97%	13 22.41%	17 29.31%	27 46.55%	0 0.00%	8 13.79%	9 15.52%	58 100.00%
25-34	1 3.70%	6 22.22%	7 25.93%	10 37.04%	3 11.11%	27 100.00%	0 0.00%	0 0.00%	1 10.00%	4 40.00%	5 50.00%	10 100.00%	15 53.57%	6 21.43%	10 35.71%	6 21.43%	5 17.86%	19 67.86%	1 3.57%	4 14.29%	4 14.29%	28 100.00%
35-44	1 25.00%	0 0.00%	1 25.00%	0 0.00%	2 50.00%	4 100.00%	0 0.00%	1 50.00%	0 0.00%	0 0.00%	1 50.00%	2 100.00%	4 66.67%	0 0.00%	0 0.00%	0 0.00%	1 16.67%	2 33.33%	2 33.33%	0 0.00%	0 0.00%	6 100.00%
45-54	2 20.00%	4 40.00%	1 10.00%	2 20.00%	1 10.00%	10 100.00%	0 0.00%	1 12.50%	3 37.50%	1 12.50%	3 37.50%	8 100.00%	2 18.18%	0 0.00%	0 0.00%	8 72.73%	4 36.36%	6 54.55%	2 18.18%	0 0.00%	2 18.18%	11 100.00%
55-65	3 42.86%	0 0.00%	3 42.86%	1 14.29%	0 0.00%	7 100.00%	2 50.00%	0 0.00%	2 50.00%	0 0.00%	0 0.00%	4 100.00%	3 42.86%	2 28.57%	0 0.00%	4 57.14%	2 28.57%	4 57.14%	0 0.00%	0 0.00%	0 0.00%	7 100.00%
Total	9 8.49%	18 16.98%	39 36.79%	27 25.47%	13 12.26%	106 100.00%	2 5.13%	2 5.13%	12 30.77%	8 20.51%	15 38.46%	39 100.00%	32 29.09%	45 40.91%	50 45.45%	31 28.18%	29 26.36%	58 52.73%	5 4.55%	12 10.91%	15 13.64%	110 100.00%

Table 7 Chi-Square Test of Age and Reasons for Becoming a Bikesharing User

How old are you?		What mainly motivated you to become a bikesharing user? If you aren't a user yet, what reason wou...
	Chi Square	89.54*
	Degrees of Freedom	96
	p-value	0.67

*Note: The Chi-Square approximation may be inaccurate - expected frequency less than 5.

Table 8 Cross-Tabulation of Age and Reasons for Becoming a Bikesharing User

		Convenience	Fun	Health benefits	Environmental benefits	Financial savings over public transport	Financial savings over car use	Marketing/advertising	Positive experience from a friend/colleague/family member	Experience using a similar system in another city	Shared bikes close to work	Shared bikes close to university campus	Shared bikes close to home	Shared bikes close to bus and metro station	Other	Time savings over public transport	Time savings over car use	To avoid congestion	Total
How old are you?	Under 18	1 / 0.06	0 / -0.14	1 / 0.80	1 / 0.64	0 / -0.22	0 / -0.06	0 / -0.02	0 / -0.13	0 / -0.02	0 / -0.08	1 / 0.63	0 / -0.15	0 / -0.21	0 / -0.04	0 / -0.22	0 / -0.10	1 / 0.68	1
	18-24	58 / 1.33	12 / 3.43	6 / -5.90	16 / -5.43	16 / 2.67	4 / 0.67	3 / 1.57	10 / 1.90	1 / 0.05	7 / 2.24	36 / 14.10	11 / 1.95	14 / 1.14	3 / 0.62	19 / 5.67	5 / -0.71	15 / -4.05	60
	25-34	28 / -1.28	5 / 0.57	7 / 0.85	13 / 1.93	9 / 2.11	3 / 1.28	0 / -0.74	2 / -2.18	1 / 0.51	2 / -0.46	7 / -4.32	3 / -1.67	8 / 1.36	0 / -1.23	7 / 0.11	3 / 0.05	12 / 2.16	31
	35-44	9 / 0.50	0 / -1.29	1 / -0.79	3 / -0.21	1 / -1.00	0 / -0.50	0 / -0.21	2 / 0.79	0 / -0.14	0 / -0.71	1 / -2.29	3 / 1.64	1 / -0.93	1 / 0.64	1 / -1.00	0 / -0.86	3 / 0.14	9
	45-54	11 / -0.33	0 / -1.71	3 / 0.62	6 / 1.71	0 / -2.67	0 / -0.67	0 / -0.29	2 / 0.38	0 / -0.19	1 / 0.05	0 / -4.38	1 / -0.81	2 / -0.57	1 / 0.52	1 / -1.67	3 / 1.86	6 / 2.19	12
	55-64	11 / -0.33	1 / -0.71	7 / 4.62	6 / 1.71	2 / -0.67	0 / -0.67	0 / -0.29	1 / -0.62	0 / -0.19	0 / -0.95	0 / -3.38	1 / -0.81	2 / -0.57	0 / -0.48	0 / -2.67	1 / -0.14	3 / -0.81	12
	65 or older	1 / 0.06	0 / -0.14	0 / -0.20	0 / -0.36	0 / -0.22	0 / -0.06	0 / -0.02	0 / -0.13	0 / -0.02	0 / -0.08	0 / -0.37	0 / -0.15	0 / -0.21	0 / -0.04	0 / -0.22	0 / -0.10	0 / -0.32	1
	Total	119	18	25	45	28	7	3	17	2	10	46	19	27	5	28	12	40	126

Table 9 Chi-Square Test of Motivational Factors for Becoming a Bikesharing User and Reduction in Car Use

		I have replaced trips by car with trips made by public transit and bikesharing.	As a result of my use of bikesharing, - I use a taxi/carsharing (e.g. Didi, Uber, etc.)
Reasons for using bikesharing	Chi Square	55.85*	81.71*
	Degrees of Freedom	64	64
	p-value	0.76	0.07

Note: The Chi-Square approximation may be inaccurate - expected frequency less than 5.

Table 10 Chi-Square Test of Trip Purpose and Reduction in Car Use

		I have replaced trips by car with trips made by public transit and bikesharing.	As a result of my use of bikesharing, - I use a taxi/carsharing (e.g. Didi, Uber, etc.)
What is the purpose of your trip? Please choose max. 3 answers.	Chi Square	30.51*	24.89*
	Degrees of Freedom	32	32
	p-value	0.54	0.81

Note: The Chi-Square approximation may be inaccurate - expected frequency less than 5.

Dockless Bikesharing Systems in China - A Case Study of Beijing

---

Q1 Thank you for agreeing to take part in this survey. Your responses are highly appreciated and help me assess the performance and impact of dockless bikesharing systems in Beijing. All your answers are kept anonymous and strictly confidential.

Directions: To answer the questions, please fill in the appropriate boxes representing your answer. For some questions, you can only choose one answer per question and for others, you can choose multiple answers. The maximum number of answers you can choose is indicated in the question so please only choose the most important answers for yourself. As it is highly important that you do not accidentally tick the wrong box, PLEASE READ EACH QUESTION CAREFULLY.

Introduction: Dockless bikesharing systems
This survey focuses on dockless shared bikes and aims to analyze the success of bikesharing systems and their impact on modal shifts in Beijing. In contrast to the first three generations of bikesharing, dockless bikes do not need to be returned to fixed docking stations and can be picked up and left anywhere. Mobike and Ofo, the two largest bikesharing companies in China, charge between **0.5 yuan** to **1 yuan** (7 to 14 Euro cents) for 30 minutes and in some cases (e.g. trial periods etc.) the use is even for free. Therefore, dockless bikesharing systems provide users with an affordable and convenient way of transportation.

X→

Q2 Have you ever used a dockless bike (e.g. Ofo, Mobike, etc.)? A dockless bike is a bike that you can leave anywhere you want without having to return it to docking stations.

○ Yes (1)

○ No (0)

Display This Question:

If Have you ever used a dockless bike (e.g. Ofo, Mobike, etc.)? A dockless bike is a bike that you c... = Yes

X→ X→

Q3 From how many different bikesharing operators do you have an account?

○ None (1)

○ Just one (2)

○ At least from 2 different operators (3)

○ From 3-5 different operators (4)

○ More than 5 (5)

✻ X→ X→

Q4 What mainly motivated you to become a bikesharing user? If you aren't a user yet, what reason would make you consider becoming a user? Please choose max. 5 answers.

- ☐ Convenience (1)
- ☐ Fun (2)
- ☐ Health benefits (3)
- ☐ Environmental benefits (4)
- ☐ Financial savings over public transport (5)
- ☐ Financial savings over car use (6)
- ☐ Marketing/advertising (7)
- ☐ Positive experience from a friend/colleague/family member (8)
- ☐ Experience using a similar system in another city (9)
- ☐ Shared bikes close to work (10)
- ☐ Shared bikes close to university campus (11)
- ☐ Shared bikes close to home (12)
- ☐ Shared bikes close to bus and metro station (13)
- ☐ Time savings over public transport (14)
- ☐ Time savings over car use (15)
- ☐ To avoid congestion (16)
- ☐ Other (17) _____

✳ X→ X→

Q5 Why are you not using a shared bike? Please choose max. 5 answers.

☐   I don't want to wear a helmet (1)

☐   I don't own a helmet (2)

☐   I'm concerned about my safety due to the traffic (3)

☐   Driving is more convenient (4)

☐   Public transport is more convenient (5)

☐   Car sharing is more convenient (e.g. Didi, Uber) (6)

☐   I find my own bike sufficient (7)

☐   There are no shared bikes close enough to my home (8)

☐   Shared bikes are not close enough to my work (9)

☐   Shared bikes are not close enough to places I like to visit (10)

☐   It's too costly (11)

☐   The deposit is too high (12)

☐   I am not sure how to sign up (13)

☐   It's too complicated or time consuming to sign up (14)

☐   Smog/air pollution (15)

☐   Weather conditions (too hot, cold, rainy or windy) (16)

☐   Other (17) _____

End of Block: Usage of Bike Sharing Systems

X→

Q6 Have you ever had any problems with a shared bike such as being unable to continue or even start your journey due to something being broken?

○ No (0)

○ Yes (1)

○ No, but my friends/colleagues/family members (2)

Q7 The following questions (Questions 10-20) are all based on your experience of using dockless bikesharing systems in ***Beijing***. Dockless bikes do not need to be returned to fixed docking stations and can be picked up and left anywhere.

X→ X→

Q8 How do you feel when sharing the same road with a bicycle user while driving a car?

○ Very safe (1)

○ Somewhat safe (2)

○ Neutral (3)

○ Somewhat unsafe (4)

○ Very unsafe (5)

○ I don't drive or own a car (6)

X→

Q9 How would you feel when riding a shared bike on the road yourself?

◯ Very safe (1)

◯ Somewhat safe (2)

◯ Neutral (3)

◯ Somewhat unsafe (4)

◯ Very unsafe (5)

Q10 How satisfied are you with the number of designated bike lanes/roads in Beijing? Please use the slider to indicate your level of satisfaction.

	0 10 20 30 40 50 60 70 80 90 100
0 ()	

Q11 Attitudes on **_Beijing_** Cycling Conditions and Environmental Issues

	Strongly agree (1)	Agree (2)	Neutral (3)	Disagree (4)	Strongly disagree (5)
The weather is suitable for cycling (Q11_1_weather)	○	○	○	○	○
The price of public transit is expensive (Q11_2_public transit expensive)	○	○	○	○	○
Public transit is often crowded (Q11_3_public transit crowded)	○	○	○	○	○
Waiting time for public transit is often long (Q11_4_long waiting time)	○	○	○	○	○
Motor vehicle usage is an important reason for environmental problems (Q11_5_motor vehicle environment)	○	○	○	○	○
I'd be willing to ride a bicycle or take public transit to help improve air quality (Q11_6_bike to improve airQ)	○	○	○	○	○
Global warming is currently happening (Q11_7_gobal warming)	○	○	○	○	○
Global warming is caused by human activity (Q11_8_global warming humans)	○	○	○	○	○

X→ X→

Q12 How many times did you use bike sharing in one month (when you were in China)?

○ 0 (1)

○ 1-3 (2)

○ 5-10 (3)

○ 11-20 (4)

○ 21-30 (5)

○ more than 30 (6)

X→ X→

Q13 What needs to be improved regarding dockless bikesharing systems? Please rank the answers below.
_____ Too many broken/unusable bikes (1)
_____ Cannot find a bike when needed (2)
_____ Bikes are overcrowding/cluttering the sidewalks and roads (3)
_____ There are not enough designated parking areas for the bikes (4)
_____ There are too many different bikesharing companies/operators (5)
_____ Insufficient government control (6)
_____ Simplify sign-up process (7)
_____ Unsuitable infrastructure for cycling (8)
_____ Other (9)

X→

Q14 How much time did you spend on riding a shared bike each time (on average)?

○ <30 mins (1)

○ >30 mins but   (2)

○ >1.5 hours but   (3)

○ >3 hours (4)

X→

Q15 I think the bikesharing system is an enhancement to the public transportation system in Beijing.

○ Strongly agree (1)

○ Agree (2)

○ Neutral (3)

○ Disagree (4)

○ Strongly disagree (5)

X→

Q16 Since joining bikesharing, I have made trips with public transit and bikesharing (together) that I would have previously done with a car.

○ Always (1)

○ Most of the time (2)

○ About half the time (3)

○ Sometimes (4)

○ Never (5)

X→ X→

Q17 As a result of my use of bikesharing,

	Much more often (1)	More often (2)	Less often (3)	Much less often (4)	No change as a result of the use of bikesharing (5)	Not applicable (6)
I use public transportation (Q17_1_public transit)	○	○	○	○	○	○
I drive a car (Q17_6_car)	○	○	○	○	○	○
I use a taxi/car sharing (e.g. Didi, Uber, etc.) (Q17_2_taxi didi)	○	○	○	○	○	○
I walk (Q17_3_walk)	○	○	○	○	○	○
I ride a bicycle (any bicycle) (Q17_4_bike)	○	○	○	○	○	○
I shop at locations near existing shared bikes (Q17_5_shopping)	○	○	○	○	○	○

✱ X→ X→

Q18 What is the purpose of your trip? Please choose max. 3 answers.

- ☐ Commuting to work (1)

- ☐ Commuting to school/university (2)

- ☐ Getting around on campus (3)

- ☐ Going shopping (4)

- ☐ Sightseeing (5)

- ☐ Getting to a metro/bus/train station (6)

- ☐ Getting around after going out/partying/drinking (7)

- ☐ There are no other alternative transportation modes available (8)

- ☐ Other (9) _____

X→

Q19 When do you usually use a shared bike?

- ○ On weekdays (1)

- ○ On weekends (2)

- ○ Both (3)

End of Block: Bikesharing in Beijing

Start of Block: Demographics

Q20 We are almost done! But before we finish I would love to get to know you a little bit better!

X→

Q21 Where are you from (country/region you identify the most with)?

○ China (1)

○ Europe (2)

○ North America (3)

○ South America (4)

○ Africa (5)

○ Asia (not Chinese) (6)

○ Oceania (7)

X→

Q22 What is your highest education level attained?

○ Less than high school (1)

○ High school (2)

○ Some college (3)

○ Bachelor's degree (4)

○ Graduate degree (5)

○ Doctorate (6)

X→

Q23 What is your gender?

○ Male (0)

○ Female (1)

X→

Q24 What is your occupation status?

○ Student (1)

○ Employed (2)

○ Unemployed (3)

○ Retired (4)

X→

Q25 How old are you?

○ Under 18 (1)

○ 18-24 (2)

○ 25 - 34 (3)

○ 35 - 44 (4)

○ 45 - 54 (5)

○ 55 - 64 (6)

○ 65 or older (7)

Page Break ———————————————————————

Q26
Thank you for taking the time to answer this survey and helping me graduate from university! Your response has been recorded.

I promise I'll share my bike with you if you need! :)

End of Block: Demographics

Works Cited

(2011). Retrieved from European Commission.

Addison, A. (2009, December 31). Hong Kong's roads clogged with supercars.

Altrock, S., & Suh, A. (2017). Sharing Economy Versus Access Economy: A Critical Reflection on Social Interaction Between Peers. *Lecture Notes in Computer Science.* Springer, Cham.

Arden Pope III, C., Burnett, R. T., Thun, M. J., Calle, E. E., Krewski, D., Ito, K., & Thurston, G. D. (2002, March 6). Lung Cancer, Cardiopulmonary Mortality and Long-term Exposure to Fine Particulate Air Pollution. *American Medical Association, 287*(9).

Assem, M. v. (2013, June 13). *Behavioral Economics and a Nudge to Reduce Car Usage.* Retrieved from School of Business and Economics, Vrije Universiteit Amsterdam: https://sbe.vu.nl/en/Images/Behavioral_economics_and_a_nudge_to_reduce_car_usage_tcm258-413194.pdf

Botsman, R. (2013). *The sharing economy lacks a shared definition.* Retrieved from http://www.fast-coexist.com/3022028/the-sharing-economy-lacks-a-shared-definition

Branigan, T. (2014, September 10). Riding Beijing's subway end to end: 88km of queues and crushes on a 20p ticket. *Cities in motion.*

Buehler, R., & Pucher, J. (2011, January). Making public transport financially sustainable. *Transport Policy, 18*(1), 126-138.

Castro, A. (2017, 1 12). (J.-J. Witte, Interviewer)

Chang, S., Song, R., He, S., & Qiu, G. (2018). Innovative Bike-Sharing in China: Solving Faulty Bike-Sharing Recycling Problem. *Journal of Advanced Transportation.*

Chris. (2017, July 6). *What Is The Sharing Economy? .* Retrieved from Rentzi: https://rentzi.com/posts/what-is-the-sharing-economy

Cohen, B., & Kietzmann, J. (2014). Ride On! Mobility Business Models for the Sharing Economy. *Organization & Environment, 27*(3), 279-296.

Cui, W. (2018). *Effects of Urban Density on the Efficiency of Dockless Bike Sharing System - A Case Study of Beijing, China.* Master Thesis, Arizona State University, School of Geographical Sciences and Urban Planning.

de Chardon, M. (2016). *A Geographical Analysis of Bicycle Sharing Systems.* University of Luxembourg.

DeMaio, P. (2009). Bike-sharing: History, Impacts, Models of Provision, and Future. *Journal of Public Transportation, 12*(4).

Eckhardt, G. M., & Bardhi, F. (2015, January 28). The Sharing Economy Isn't About Sharing at All. *Harvard Business Review.*

eMarketer. (2015, May 4). Retrieved from The Sharing Economy: Users Desire 'Access Over Ownership': https://www.emarketer.com/Article/Sharing-Economy-Users-Desire-Access-Over-Ownership/1012429

Fishman, E. (2016). Bikeshare: A Review of Recent Literature. *Transport Reviews, 36*(1), 92-113.

Fishman, E., Washington, S., & Haworth, N. (2013). Bike share: a synthesis of the literature. *Transport Reviews, 33*(2), 148-165.

Friedman, N. (2017). (J.-J. Witte, Interviewer)

Gärling, T., Eek, D., Loukopoulos, P., Fujii, S., Johansson-Stenman, O., Kitamura, R., . . . Vilhelmson, B. (2002). A conceptual analysis of the impact of travel demand management on private car use. *Transport Policy, 9*, 59-70.

Garrard, J., Crawford, S., & Hakman, N. (2006). *Revolutions for women: increasing women's participation in cycling for recreation and transport, summary of key findings.* Melbourne: Deakin University.

Gebhart, K., & Noland, R. B. (2014, November). The impact of weather conditions on bikeshare trips in Washington, DC. *Transportation, 41*(6), 1205-1225.

Goldsmith, S. (1992). *The national bicycling and walking study case study no. 1: reasons why bicycling and walking are not being used more extensively as travel modes.* Washington DC: US Government Printing Office.

Goodman, A., & Cheshire, J. (2014). Inequalities in the London bicycle sharing system revisited: impacts of extending the scheme to poorer areas but then doubling prices. *Journal of Transport Geography, 41*, 272-279.

Goodyear, S. (2015). *The Global Bike-Share Boom: An Interactive History*. Retrieved from Citilab: https://www.citylab.com/city-makers-connections/bike-share/

Grabow, M. L., Spak, S. N., Holloway, T., Stone, B., Mednick, A. C., & Patz, J. A. (2012, Jan). Air Quality and Exercise-Related Health Benefits from Reduced Car Travel in the Midwestern United States. *Environmental Health Perspecitves, 120*(1), 68-76.

Handy, S., Wee, B. v., & Kroesen, M. (2014). Promoting cycling for transport: research needs and challenges. *Transport Reviews: A Transnational Transdisciplinary Journal, 34*(1), 10-15.

Hartog, J. J., Boogaard, H., Nijland, H., & Hoek, G. (2010, June 30). Do the Health Benefits of Cycling Outweigh the Risks? *Environmental Health Perspectives, 118*(8), 1109-1116.

Hernández, J. C. (2017, September 2). As Bike-Sharing Brings Out Bad Manners, China Asks, What's Wrong With Us? *The New York Times* .

Jacobs, H. (2018, July 31). I tried the two Chinese bike-sharing giants trying to take over the world, and it was immediately obvious why they can't seem to crack the US. *Business Insider*.

Jenkins, K. (2017, June 27). Half of Chinese Adults have Prediabetes or Diabetes.

Jiang, H. (2018, January 12). *Chinese Cities Aim to Rein in Bike-Sharing Boom*. Retrieved from World Resources Institute: http://www.wri.org/blog/2018/01/chinese-cities-aim-rein-bike-sharing-boom

Jordan, J. (2018, April 20). How can dockless bike and scooter companies make money? . (R. Nikolewski, Interviewer)

Kade, A. (2013, October 02). *World's Most Crowded Subways*. Retrieved from Travel and Leisure: https://www.travelandleisure.com/slideshows/worlds-most-crowded-subways

Kahneman, D., & Tversky, A. (1979). Prospect Theory: An Analysis of Decision under Risk. *Econometrica, 47*(2).

Larsen, J. (2013). *Bike-Sharing Programs Hit the Streets in Over 500 Cities Worldwide*. Retrieved from Earth Policy Institute: http://www.earth-policy.org/plan_b_updates/2013/update112

Liu, H., Jia, X., & Cheng, W. (2012). Solving the Last Mile Problem: Ensure the Success of Public Bicycle System in Beijing. Changsha: 8th International Conference on Traffic and Transportation Studies.

Lohry, G. F., & Yiu, A. (2015). Bikeshare in China as a public service: Comparing government-run and public-private partnership operation models. *Natural Resources Forum, 39*, 41-52.

Ma, Y., Lan, J., Thornton, T., Mangalagiu, D., & Zhu, D. (2018). Challenges of collaborative governance in the sharing economy: The case of free-floating bike sharing in Shanghai. *Journal of Cleaner Production, 197*, 356-365.

Mead, N. V. (2017, March 22). Uber for bikes: how 'dockless' cycles flooded China - and are heading overseas.

Meddin, R. (2017, January 25). *The Bike-sharing World at the End of 2016*. Retrieved from The Bike-sharing Blog: http://bike-sharing.blogspot.com/2017/01/the-bike-sharing-world-at-end-of-2016.html

Meddin, R., & DeMaio, P. (2015). *The bike-sharing world map*. Retrieved from Bike Sharing World : www.bikesharingworld.com

Mobike. (2018). *How cycling changes cities - insights on how bikesharing supports urban development.* Mobike.

Nakamura, Y. (2017, August 10). *China cracks down on bike-sharing in 8 cities*. Retrieved from Nikkei Asian Review: https://asia.nikkei.com/Economy/China-cracks-down-on-bike-sharing-in-8-cities

Nazelle, D. R.-R., Tainio, M., & Nieuwenhuijsen, M. J. (2011). The health risks and benefits of cycling in urban environments compared with car use: health impact assessment study. *BMJ*.

Ni, D. (2017, March 27). Child's Death Reveals Growing Pains of Bike Sharing . *Sixth Tone* .

Nielse, B. H. (1993). The Bicycle in Denmark: Present Use and Future Potential. *Danish Ministry of Transport, 52*.

Nikolewski, R. (2018, April 20). How can dockless bike and scooter companies make money? *The Star Online*.

O'Brien, O. (2018, February 21). *Future Transport Report and Bikeshare in London*. Retrieved from Suprageography: http://oobrien.com/2018/02/future-transport-report-and-dockless-in-london/

O'Dwyer, S. (2017, 1 10). (J.-J. Witte, G. Mingardo, & M. Streng, Interviewers)

Pal, A., & Zhang, Y. (2017, May 3). Free-floating bike sharing: Solving real-life large-scale static rebalancing problems. *Transportation Research Part C, 80*, 92-116.

Plant, L. (2010, June 30). *IBM Global Commuter Pain study reveals traffic crisis in key international cities*. Retrieved from IBM: https://www.ibm.com/news/ca/en/2010/06/30/o104915g16292k57.html

Poverty and Social Exclusion. (n.d.). Retrieved from Transport poverty hits 1.5 million people: http://www.poverty.ac.uk/report-transport/transport-poverty-hits-15-million-people

Reinhold, T., & Kearny, A. T. (2008). More passengers and reduced costs - optimization of the Berlin Public Transport Network. *Journal of Public Transportation, 11*, 57-76.

Reuters. (2017, August 11). Smog main suspect for rising lung cancer rate. *South China Morning Post*.

Roxburgh, H. (2018, March 19). China's radical plan to limit the populations of Beijing and Shanghai.

Rudolph, C. (2014). *Decreasing CO2 by Increasing Bicycle Use.* Hamburg : Hamburg University of Technology (TUHH), Institute for Transport Planning and Logistics: Mobile 2020 project consortium.

Schmitt, A. (2015, November 18). *How Much Can Bicycling Help Fight Climate Change? A Lot, If Cities Try*. Retrieved from Streetsblog USA: https://usa.streetsblog.org/2015/11/18/how-much-can-bicycling-help-fight-climate-change-a-lot-if-cities-try/

Shaheen, S., & Guzman, S. (2011, 10 01). Worldwide Bikesharing. *ACESS Magazine, 1*(39), 22-27.

Shaheen, S., Guzman, S., & Zhang, H. (2010). Bikesharing in Europe, the Americas, and Asia: past, present, and future. *Transportation Research Record: Journal of the Transportation Research Board*, 159-167.

Towson, J. (2017, April 10). *Opinion: Why bike-sharing isn't actually part of the sharing economy*. Retrieved from Tech in Asia: https://www.techinasia.com/talk/bikesharing-not-sharing

Tucker, R. (2017, March 24). *Idle Capacity is the Foundation of the Sharing Economy*. Retrieved from Commercial Real Estate Development Association: https://erasmusuniversity.eu.qualtrics.com/jfe/preview/SV_237wTOrKJzjrgSF?Q_SurveyVersionID=current&Q_CHL=preview

Velaga, N. R., Beecroft, M., Nelson, J. D., Corsar, D., & Edwards, P. (2012, March). Transport poverty meets the digital divide: accessibility and connectivity in rural communities. *Journal of Transport Geography, 21*, 102-112.

Wang, L., Gao, P., Zhang, M., Huang, Z., Zhang, D., Qian Deng, Y. L., . . . Wang, L. (2017). Prevalence and Ethnic Pattern of Diabetes and Prediabetes in China in 2013. *JAMA, 317*(25).

Wang, W., Wei, W., & Tian, C. (2011). Comparative study of commercial operation mode of public bicycle systems - based on a new Chinese model. *World Academy of Science, Engineering and Technology, 57*, 557-560.

Watts, J. (2011, July 11). Rich in China get richer only faster.

Yang, Y. (2017, 11 06). *More Chinese cities saying "enough is enough" to shared bikes*. Retrieved from Xinhuanet.com: http://www.xinhuanet.com/english/2017-11/06/c_136732338.htm

Yin, D., & Tan, X. (2017, November 30). *Bike-sharing Data and Cities: Lessons from China's Experience*. Retrieved from New Security Beat - the blog of the Environmental Change and Security Program: https://www.newsecuritybeat.org/2017/11/bike-sharing-data-cities-lessons-chinas-experience/

Zhang, L., Zhang, J., Duan, Z.-y., & Bryde, D. (2015). Sustainable bike-sharing systems: characteristics and commonalities across cases in urban China. *Journal of Cleaner Production, 97*, 124-133.

Zhang, Y. (2017, November 17). The Future of Bike Sharing with Ofo Cofounder Yanqi Zhang And Anu Hariharan. (A. Hariharan, Interviewer)

Zhao, P. (2014, April). The Impact of the Built Environment on Bicycle Commuting: Evidence from Beijing. *Urban Studies, 51*(5), 1019-1037.

Zhecheng, Q. (2017, December 30). *Wins and Losses in China's Bike-Sharing War*. Retrieved from Sixth Tone: http://www.sixthtone.com/news/1001480/wins-and-losses-in-chinas-bike-sharing-war

Zhou, S., Ni, Y., & Zhang, X. (2018, 1 8). Effects of Dockless Bike on Modal Shift in Metro Commuting: A Pilot Study in Shanghai. *Transportation Research Record*.

Zhu, W., Pang, Y., Wang, D., & Timmermans, H. (2013). Travel Behavior Change After the Introduction of Public Bicycle Systems: Case Study in Minhang District, Shanghai. *Transportation Research Board 92nd Annual Meeting*. Washington DC.