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Dockless bike-sharing systems: what are the implications?

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ABSTRACT

The emergence of dockless bike-sharing services has revolutionised bike-sharing markets in recent years, and the dramatic growth of shared bike fleets in China, as well as their rapid expansion throughout the world, exceeds prior expectations. An understanding of the impacts of these new dockless bike-sharing systems is of vital importance for system operations, transportation and urban planning research. This paper provides a first overview of the emerging literature on implications of dockless bike-sharing systems for users' travel behaviour, user experience, and relevant social impacts of dockless bike-sharing systems. Our review suggests that the dockless design of bike-sharing systems significantly improves users' experiences at the end of their bike trips. Individuals can instantly switch to a dockless shared bike without the responsibility of returning it back to a designated dock. Additionally, the high flexibility and efficiency of dockless bike-sharing often makes the bike-sharing systems' integration with public transit even tighter than that of traditional public bikes, providing an efficient option for first/last-mile trips. The GPS tracking device embedded in each dockless shared bike enables the unprecedented collection of large-scale riding trajectory data, which allow scholars to analyse people's travel behaviour in new ways. Although many studies have investigated travel satisfaction amongst cyclists, there is a lack of knowledge of the satisfaction with bikeshare trips, including both station-based and dockless bikeshare systems. The availability and usage rates of dockless bike-sharing systems implies that they may seriously impact on individuals' subjective well-being by influencing their satisfaction with their travel experiences, health and social participation, which requires further exploration. The impact of dockless bike-sharing on users' access to services and social activities and the related decreases in social exclusion are also relevant issues about which knowledge is lacking. With the increases in popularity of dockless shared bikes in some cities, issues related to the equity and access and the implications for social exclusion and inequality are also raised.

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1. Introduction

In recent years, municipal governments' intentions to promote sustainable modes of transportation and developments in information technology (IT) have resulted in the world wide adoption of bike-sharing systems (DeMaio, 2009; Fishman, Washington, Haworth, & Watson, 2015). Bike-sharing systems are intended to provide individuals with increased convenience and flexibility in access to bicycles without the cost and responsibility associated with bike ownership (Faghih-Imani & Eluru, 2015, 2016; Van Lierop, Grimsrud, & El-Geneidy, 2015). Shared bikes are used on an "as-needed" basis, and individuals' decisions about taking a trip can be made in a short time frame; therefore, shared bikes are especially suitable for short distance or one-way trips (Zhang, Shaheen, & Chen, 2014; Zhao, Wang, & Deng, 2015). Moreover, by acting as a catalyst for the use of bikes for regular commutes, leisure trips, and doing errands, bike-sharing systems contribute to reducing emissions and fuel usage, easing traffic congestion, and fulfilling recommended exercise requirements by integrating physical activity into daily life (Shaheen, Martin, & Cohen, 2013; WHO, 2016).

Many contemporary public bike-sharing systems facilitate short-term bike rentals going from one docking station to another. These docked-systems are usually IT-based with credit card payments and have dynamic pricing schemes (Fishman, Washington, & Haworth, 2013; Shaheen, Guzman, & Zhang, 2010). However, the difficulty of accessing docking stations is a well-known barrier that prevents the uptake of station-based bike-sharing services (Fishman, Washington, Haworth, & Mazzei, 2014), and the number of docks/stations is often restricted by space limitations in a city, and the municipal budget. The most recent generation of dockless bike-sharing systems has the potential to overcome this barrier. These new systems combine cashless mobile payments and GPS (Global Positioning System) tracking. All the necessary steps, such as locating, unlocking, and paying for the use of a bike are incorporated into a smartphone application. Since 2016, this kind of dockless system has experienced a leap in growth within China and has gradually spread to the United Kingdom, Singapore, the United States of America, and the Netherlands (Shen, Zhang, & Zhao, 2018). The scale of dockless bike-sharing systems with regard to the number of bikes and visibility differs significantly (at least in China) compared to most docked systems, potentially leading to different levels of adoption and usage patterns, which requires further discussion and investigation.

The emergence of dockless shared bikes has revolutionised the bike-sharing markets in recent years. An understanding of these dockless bike-sharing systems is of vital importance for transport and urban research, system operations, and urban and transportation planning. However, there is a paucity of knowledge about the usage of dockless bike-sharing systems and the changes it has brought to users' travel behaviour and social lives, such as their inclusion in society and well-being. In light of this, this paper provides a first overview of the emerging literature on dockless bike-sharing systems in terms of users' perspectives. The primary aim is to assess the critical themes that are important for understanding users' travel behaviour and experience, as well as the relevant social impacts of dockless bike-sharing systems. As dockless bike-sharing is a relatively newly developed travel mode, limited research is available on users' perspectives of dockless bike-sharing systems so far. This review therefore highlights the gaps in the research of dockless bike-sharing and users' perspectives, and specifies the priorities for future studies.

This review contains only English language bike-sharing literature resulting from a Google Scholar search. Although many studies on dockless bike-sharing can be found in the CNKI (China Academic Journals full-text database), they are not included in this review since most focus on the operation, management and future development of dockless shared bikes rather than on individuals' user experiences. The search terms included "bike-sharing", "bicycle-sharing", "bikeshare", "shared bikes", "public bike", "public bicycle", "dockless bikeshare", "dockless shared bikes", "dockless shared bicycles" and "dockless bike-sharing". Backward snowballing based on the reference lists of the articles found in the initial search results revealed additional relevant papers. Considering that this study is focused on assessing bike-sharing users' perspectives, a range of bike-sharing related topics, including the development, usage patterns and social implications of bike-sharing systems, has been reviewed. As the following sections show, the review encompasses studies from Europe, the Americas, Australia, and Asia. It is worth noting that due to the speedy development of docked bike-sharing literature in recent years and a potential rapid increase of studies on dockless bike-sharing, papers will have been published after our literature selection, which are not included.

2. Bike-sharing systems: an introduction

The first bike-sharing system appeared in the Netherlands in 1965 as an attempt to solve the traffic problems in Amsterdam's inner city (DeMaio, 2009). A local community organisation provided white bikes that were left permanently unlocked and placed randomly throughout the inner city for free use without time limitations. This scheme soon failed because of bike theft and vandalism. Then, in the 1990s, a second generation of coin-deposit shared bikes was introduced in Copenhagen. However, it did not solve the issue of theft because the user anonymity and lack of time limits for bike usage led to excessively long rental periods for the bikes (Shaheen et al., 2010). Despite the failure of its precedents, third-generation bike-sharing programmes, characterised by system integration (e.g. a smart card integrated with public transit) and technology advancement (e.g. transaction kiosks at the docking stations), have gained worldwide popularity (DeMaio, 2009; Shaheen et al., 2010). Examples of third generation bike-sharing systems include BIXI in Montreal, the Velib' bicycle-sharing system in Paris, and Hangzhou Public Bicycle in China.

In 2016, a number of private, app-based dockless bike-sharing programmes began competing in major Chinese cities and quickly expanded. The authors define this updated system as the fourth-generation of bike-sharing, which moves beyond the widely accepted three generations mentioned in the literature (Parkes, Marsden, Shaheen, & Cohen, 2013). According to the Research Report on Bike-sharing Employment, dockless bike-sharing operators in China (including the two largest operators, Ofo and Mobike) have approximately 16 million bikes and, on average, aggregate over 50 million orders per day (State Information Centre, 2017). Figure 1 provides a timeline and overview of the evolution of bike-sharing systems.

3. Existing research on docked bike-Sharing systems

Existing research and findings across a range of station-based bike-sharing users' perspective topics, such as bike-sharing usage, mode substitution, user demographics and

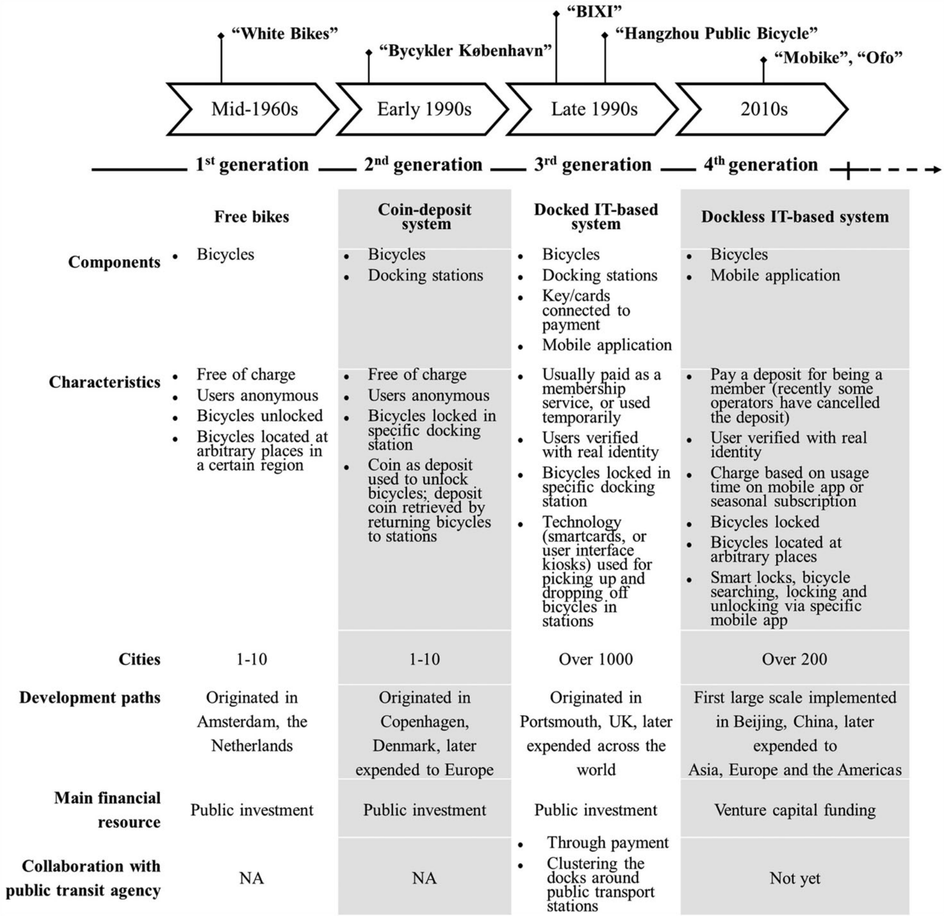

Figure 1. Bike-sharing system generations.

preferences, trip purposes, and the social impacts of docked shared bikes distribution across stations, have provided a grounding for the exploration of dockless bike-sharing systems. This section summarises what is known about docked bike-sharing systems in terms of users' perspectives.

Users' travel behaviour with station-based shared bikes can vary dramatically across bike-sharing programmes in different cities. There have been massive differences in the station-based bike-sharing usage rates globally, as Barcelona reached an average of six to seven trips per day per bike while Brisbane had only approximately 0.3 trips per day per bike (in 2011) (Fishman et al., 2013). However, many similarities also exist. The weekday usage of shared bike users has been commonly found to show a morning peak between 7 and 9 am and an afternoon peak between 4 and 6 pm, indicating that a large percentage of shared bike travel is done for commuting purposes, whereas weekend usage tends to be strongest in the middle of the day, suggesting patterns of cycling for more recreational or subsistence purposes (Fishman, 2015). The trip duration of bike-sharing journeys tends to be relatively short. Research on the public bike systems in Melbourne, Brisbane, Washington, DC, Minnesota and London has claimed that the duration of trips generally falls between 16 and 22 mins (Fishman, Washington, & Haworth, 2014).

In all regions, the majority of docked bike-sharing trips were found to mainly be a substitute for walking or public transit trips, and substitution of private motor vehicle use was limited (Fishman, 2015; Murphy & Usher, 2014; Shaheen, Zhang, Martin, & Guzman, 2011). Nevertheless, according to research on several station-based bike-sharing systems in different cities worldwide, bike-sharing reduces car use to some extent (Shaheen et al., 2011; Shaheen et al., 2013). Bike-sharing systems can serve as a segment of longer intermodal trips, increasing the catchment area of public transit and bridging the gap in existing transport networks (Jäppinen, Toivonen, & Salonen, 2013; Shaheen et al., 2013). Studies of the integration of bike-sharing and public transit indicate strengthened benefits to both modes (Fishman et al., 2013; Fishman et al., 2015), and a potential substitution of car journeys. For example, Shaheen et al. (2013) found that in Montreal and Toronto, Canada, 41% and 28% of the respondents, respectively, reported that public transit in combination with shared bikes replaced former car trips. In terms of travel purpose, different types of users (such as regular and occasional users) and users of divergent socio-demographics (determined by age, gender, car ownership, etc.) tend to use bike-sharing for different trip purposes. In both Washington, DC and Brisbane, Australia, long-term members of bike-sharing systems were found to be more likely to report using shared bikes for work-related trips, while occasional users seldom claimed commuting to be the purpose of their trips (Buck et al., 2013; Fishman et al., 2015).

Research on traditional station-based bike-sharing systems suggests that individual characteristics, perceptions, attitudes, and the built environment influence users' travel patterns. Previous studies identified that males and younger populations account for a larger percentage of docked bike-sharing users (e.g. Fuller et al., 2011; Heinen, Kamruzzaman, & Turrell, 2018; Heinen, van Wee, & Maat, 2010). Studies on docked bike-sharing systems in Beijing, Shanghai and Hangzhou also revealed that docked bike-sharing users have higher levels of car ownership than non-users (Fishman et al., 2013). Regarding income status, Goodman and Cheshire (2014) conducted research on the London bicycle sharing system and discovered that users of shared bikes tend to be wealthier than the general population, consistent with previous findings from London, Washington and Hangzhou (e.g. Ogilvie & Goodman, 2012; Shaheen et al., 2011). Apart from socio-demographic characteristics, individuals' perceptions of facilitators and barriers to the usage of station-based bike-sharing programmes have been explored (Damant-Sirois & El-Geneidy, 2015). Convenience has been regarded as a major benefit by docked bike-share users (e.g. Shaheen et al., 2013), and the perception of a lack of safety is found in many studies to be a major barrier to cycling (e.g. Buck & Buehler, 2012; Fishman et al., 2014). Individuals' attitudes towards travel modes and environmental implications are suggested to influence the participation and usage of docked bike-sharing systems (Damant-Sirois & El-Geneidy, 2015; Fernández-Heredia, Monzón, & Jara-Díaz, 2014; Fishman et al., 2015). Having a pro-environment attitude, which usually correlates with possessing a pro-bike attitude and an awareness of the physical benefits of cycling, is often positively associated with docked bike-sharing usage (Heinen, Maat, & van Wee, 2011, 2012).

Built environment characteristics near bike-sharing stations, such as population density, job density, bicycle and public transit infrastructure, street design, land-use mix and proximity to central areas, have been found to exert an effect on station-based bike-sharing usage. Buck and Buehler (2012) analysed the Capital Bikeshare system in Washington, DC and found a significant positive correlation between bike lanes, population density, mixed land-use and bike-sharing usage. Similar results have been found by Rixey (2013), who examined three U.S. public bike-sharing system and identified significant positive associations were between population density, job density, presence of bicycle lanes, as well as proximity to bike-sharing stations and the cycling frequencies. Faghih-Imani, Eluru, El-Geneidy, Rabbat, and Haq (2014) used real time station data from the BIXI system in Montreal, Canada and found that a higher proximity to central business district was associated with decreasing departure and arrival rates at BIXI stations. They also suggested that BIXI was likely used for daily commuting trips as job density displayed a positive correlation with arrival rates at stations from 6:00 to 10:00 am and a negative correlation between 3:00 and 7:00 pm.

Consistent evidence suggests that station-based bike-sharing systems are likely to produce a pattern of engagement with younger, more educated, and more affluent groups regardless of different national or local contexts (e.g. Fishman et al., 2015; Ricci, 2015; Shaheen, Cohen, & Martin, 2013). Ursaki and Aultman-Hall (2016) revealed race, education, and income disparities concerning shared bike services in Chicago, Denver, Seattle and New York City as well as household income differences in Washington, DC and Arlington. They claimed that the finding that more traditionally disadvantaged groups have less access to bike-sharing held true in all the cities they measured. However, residents in more marginalised areas will and do use docked shared bikes more if these systems are accessible and affordable to them. Ogilvie and Goodman (2012) examined the inequalities in London's Barclays Cycle Hire scheme and found that users in the more marginalised areas made more trips by shared bikes than did users in less-marginalised areas after adjusting for the lower likelihood of marginalised areas being close to shared bike stations. Looking at the same bike-sharing scheme, Goodman and Cheshire (2014) found that the 2012 scheme extension to some of London's poorest areas largely increased the proportion of trips by registered users from highly marginalised areas. However, the doubling of prices decreased the usage of casual trips among residents of poorer areas.

4. Dockless vs. Docked bike-sharing systems

The growth of dockless bike-sharing systems is a response to the challenges that traditional station-based bike-sharing systems have faced in expanding their scale in terms of the convenience, accessibility, the limited availability of space and the need for public subsidies. A principal feature of this new bike-sharing system is that it depends largely on a smartphone application, the embedded GPS on every bike and internet to locate and unlock the bikes, and that there are no fixed bicycle parking stations or docks. The location of the shared bicycles depends on where the previous users drop off the bikes. Thus, dockless shared bike users often also have to walk out of their way to access a bike and begin a bike-share trip. However, the dockless design avoids walking at the destination, as individuals are not restricted to ending their trips at docking stations. This advantage frees users from the necessity of a dock for a shared bike along their routes or around their destinations. In addition, as the connection of traditional docked systems with public transit relies largely on the number of docks available, the pressure of drop-off restriction and space limitation around public transit stations is lower in a dockless system. A higher number of docks requires more extensive economic and human resources. With similar economic and social input, dockless systems are able to operate more efficiently than the docked bike-sharing systems (Mooney et al., 2019).

On the other hand, dockless shared bikes floating freely across the operating areas generate the concern of regulation and distribution, directly affecting people's usage and experience of the services. The deregulated nature of the system has triggered the appearance of irregular parking behaviour among a non-negligible number of users, resulting in negative impacts such as violating pedestrian rights, blocking cycle paths, and hindering the flows of metro users (Chang, Song, He, & Qiu, 2018; Shi, Si, Wu, Su, & Lan, 2018). Meanwhile, as dockless bike-sharing systems are often supported by venture capital funding, it allows privately operated companies to avoid the regularly lengthy government approval processes associated with traditional public station-based systems, which led to the rapid introduction, duplication and also withdrawal of the service by different operating companies in many regions. In China, the competition for markets at the early stage among different operating companies has led to an exceeding supply of dockless bike-sharing systems (Gu, Kim, & Currie, 2019). In combination with inadequate redistribution schemes, this has also led to a large amount of abandoned or damaged bikes remaining on the streets without timely maintenance or clearance. As the redistribution of shared bikes occurs on a larger geographic scale rather than in-between different docking stations in docked bike-sharing systems, controlling and regulating shared bikes becomes more difficult in regions that have dockless systems.

Based on the comparison of these two generations of bike-sharing systems, Figure 2 summarises the similarities and differences between docked and dockless bike-sharing systems from three users' aspects: (a) service usage, (b) last mile implications and (c) accessibility and distribution.

5. Implications of dockless bike-sharing systems

Despite the partial similarities between dockless and station-based bike-sharing systems, the distinctive characteristics of dockless bike-sharing systems may lead to different

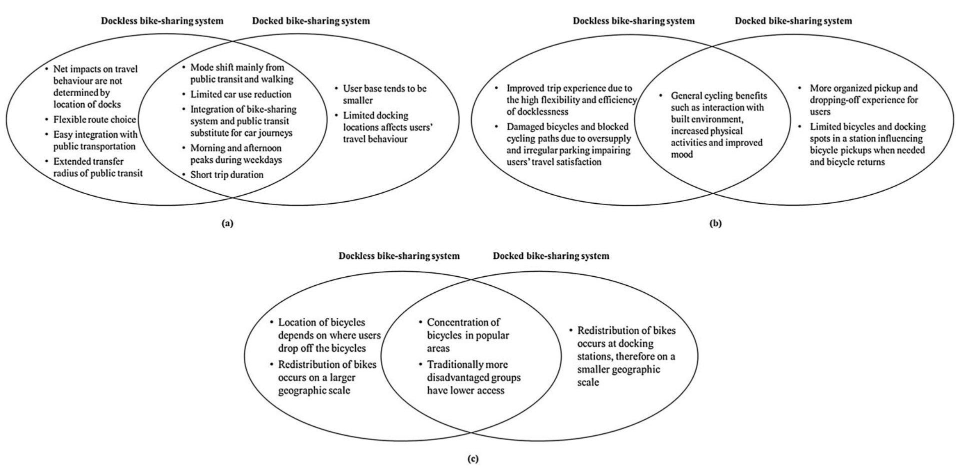

Figure 2. Similarities and differences between docked and dockless bike-sharing systems. (a) Service usage. (b) Last mile implications. (c) Accessibility and distribution.

outcomes in terms of travel behaviour and social implications related to inclusion and well-being. This section will begin by presenting a discussion of the evidence on dockless bike-sharing usage, which highlights the travel behaviour of users and summarises the determinants of usage presented in the relevant literature. This discussion is followed by an analysis on the social implications of dockless bike-sharing systems. It should be noted that, only limited research is available on the implications of dockless bike-sharing systems. Therefore, for themes where no studies of dockless bike-sharing are available, the authors develop hypotheses based on the comparison between existing literature on conventional bike-sharing and the known distinctive characteristics of dockless bike-sharing.

5.1. Travel behaviour

Dockless bike-sharing systems have the potential to either decrease (via the substitution of short trips by public transit) or increase (by supporting multimodal connections) public transit use according to different context, similar to docked bike-sharing systems (Martin & Shaheen, 2014). The advantages of improved users' experience at the end of their rides and flexible route and destination choices, however, give dockless bike-sharing systems higher flexibility and efficiency, which often contribute to a tighter integration with public transportation than traditional public bikes have. In Beijing, approximately 81% and 44% of shared bikes from Mobike, one of the largest dockless bike-sharing operators in China, were found to be active around bus stops and metro stations, respectively (these data refer to trips starting within 300 m of a bus stop and 500 m of a metro station; there is a partial overlap between the area surrounding the metro and bus stations) (Mobike Global, Beijing Tsinghua Tongheng Planning and Design Institute, & China New Urbanization Research Institute, 2017). Moreover, dockless bike-sharing systems manage to extend the transfer radius of public transit. In their study on dockless bike-sharing systems, Ai, Li, and Gan (2018) found that shared bikes were complementary to walking transfers from one public transport to another, as most walking transfers ranged from 50 to 250 m, whereas most dockless bikeshare-based transfers were between 200 and 400 m.

A Mobike white paper report written with the support of the China New Urbanization Research Institute at Tsinghua University was released on 12 April 2017 in association with Beijing Tsinghua Tong Heng Planning and Design Institute (Mobike Global et al., 2017). This report roughly demonstrates how shared bikes change the way people travel in China based on an analysis of bike-sharing GPS trip data from Mobike and user questionnaires in 36 cities. The results revealed that one-third of the users ride shared bikes for leisure, while one-fifth integrate their bike-sharing rides with public transit. Similar to studies on station-based public bike-sharing systems, the trip purposes of dockless bike-sharing trips indeed diverged according to users' profiles, with individuals born in the 1980s and 1990s using dockless shared bikes more for commuting or for accessing education, and older users (born in the 1940s and 1950s) travelling more for obtaining food and going shopping. Additionally, this research presented an indication of a mode shift towards bike usage. Before the advent of shared bikes, the proportion of bike usage in China accounted for only 5.5% of urban transport. Then, this figure doubled to 11.6%. To a limited extent, the use of shared bikes reduced the reliance on private cars, with the proportion of private car trips decreasing by approximately 3.2% after the appearance of shared bikes. The role of shared bikes as an alternative to the use of illegal auto-rickshaws is remarkable. Mobike users who participated in the survey reported that their trips via illegal auto-rickshaw had been reduced by more than 50%. However, this research did not consider walking trips. Further research is needed to understand whether and to what extent dockless bike-sharing trips are substituted for walking trips.

While station-based bike-sharing systems provide station-level data with only information about the origins and destinations of trips, the imbedded GPS located in all dockless shared bikes keeps track of the exact routes taken by users, creating a massive number of records on travel trajectories. These provide detailed insight into bike-sharing users' temporal and spatial mobility patterns. A study conducted by Bao, He, Ruan, Li, and Zheng (2017) in Shanghai displayed two key spatial mobility patterns from Mobike data. "Spatial hot spots" describe the areas with the highest number of trip origin points, such as the terminal station of a subway line and a popular shopping mall. Starting from these "spatial hot spots", the study found that the shared bike trips extended in different directions from the same departure location in a "star-like mobility pattern". Information about bike-sharing trip distance (70% of the trips were within 2 kilometres), trip duration (most trips were under 30 mins) and trip temporal distribution (usage peaked in the morning/evening rush hours) were also revealed in this study and were generally consistent with what was found from the GPS data of the dockless bike-sharing systems in Singapore (Shen et al., 2018). These trip patterns also resemble those of traditional station-based bike-sharing systems. Additionally, the study by Bao et al. (2017) confirmed an integration of the dockless bike-sharing systems and public transit by analysing the Mobike trajectory starting and ending locations in different time period. In the early morning (around 6:00 to 8:00 am) a large percentage of trip origins concentrated at residential areas and then gradually shifted to the subway stations between approximately 8:00 and 10:00 am. In combination with the analysis of the destinations of trips in these two different periods, this observation was also found in line with the assumption of dockless bike-sharing systems as a "last-mile solution". As dockless shared bikes can be dropped off at arbitrary places, the travel trajectories more accurately reflect travel demands. The origin of a trip also reveals the convenient drop-off location for the previous bike-sharing user, which is unique compared to traditional docked systems. These advantages that come from the collection of the trajectory data constitute a useful instrument for improving urban low-speed transport systems and land use planning. Using large-scale Mobike trajectory data in Shanghai, the same study by Bao et al. (2017) proposed an approach for developing construction plans for cycling pathways.

5.2. Determinants of travel behaviour

Research on traditional station-based bike-sharing systems has suggested the influence of individual characteristics, the social environment and the built environment on users' travel patterns. Similarly, for dockless bike-sharing systems, the Mobike report (Mobike Global et al., 2017) pointed out that in terms of total number of trips, male users make more trips than females, and individuals in their 20s, 30s, and 40s account for 70% of bike-sharing users. However, retired males were found to ride for the longest distances and have the highest riding speeds. Another study of dockless bike-sharing systems in

Nanjing by Du and Cheng (2018) found that the dockless bike-sharing adoption was high among employees and college students due to their fixed working and education commuting needs, and no large gender differences among users were revealed.

Although there has been no study, to the authors' knowledge, assessing what effects the social environment has on the usage of dockless bike-sharing, a review of research on cycling for transportation has found that one's social environment strongly influences the usage of bikes as a mode of transportation and the decision to use a bike for recreational purposes (Handy, Xing, & Buehler, 2010; Xing, Handy, & Mokhtarian, 2010). Another study revealed that social support from family or friends can significantly influence individuals to take short bike trips (Heinen et al., 2011). In addition, individuals are found to engage in cycling more often when they have family or friends who engage in cycling (de Geus, De Bourdeaudhuij, Jannes, & Meeusen, 2008; Titze, Stronegger, Janschitz, & Oja, 2008). It is, therefore, logical to speculate that one's social environment and environmental attitudes can influence dockless bike-sharing usage.

Evidence on traditional docked bike-sharing schemes has suggested an influence of the built environment around docking stations on the participation and usage rates of the services (e.g. Buck & Buehler, 2012; Rixey, 2013). As a new generation of bike-sharing, the usage of dockless bike-sharing systems can also vary across different built environment features. However, the nature of the dockless design means that it is not possible to assess the effect of the built environment at the station level. Instead, considering the built environment around the residential or working areas may shed light on better understanding of the relationship between built environment features and dockless bike-sharing usage behaviour. In addition, the availability of bike-share GPS data could also facilitate an examination of built environmental effects at the system level. For instance, a study by Shen et al. (2018) on the major dockless bike-sharing system in Singapore investigated the influence of built environment on general system usage. They divided the research area into land grid cells. Different measures of built environmental impact factors were aggregated into each cell, and the average number of bike trips per hour in each land cell was calculated using hourly dockless shared bikes location data. The results suggested that a high land use density of commercial areas, diverse economic activities, small street blocks, supportive cycling facilities and better transport infrastructure were associated with a higher hourly bike-sharing trips.

5.3. Travel satisfaction and subjective well-being

Despite the fact that recent studies have extensively examined individuals' travel experiences and trip satisfaction with different travel modes (e.g. Ettema & Smajic, 2015; Lierop, Badami, & El-Geneidy, 2018; Mao, Ettema, & Dijst, 2016), the travel experiences of bike-sharing users have not yet drawn attention among researchers. Generally, cycling and walking are frequently found to be the most satisfying travel modes when compared to automobile and public transport in many different contexts, such as China, the Netherlands and Canada (Ettema & Smajic, 2015; Mao et al., 2016; St-Louis, Manaugh, van Lierop, & El-Geneidy, 2014). Cycling enables individuals to interact with the environment, which offers sufficient but not overwhelming stimulation, and the associated physical activity can improve users' moods (Ekkekakis, Hall, & Petruzzello, 2008; Ettema & Schekkerman, 2016; Gatersleben & Uzzell, 2007). Dockless bike-sharing systems possess these features and, at the same time, provide increased flexibility in access to bikes without the maintenance cost and responsibility of bike ownership, freeing individuals from securing and maintaining their bikes, which can, to an extent, have a beneficial influence on users' satisfaction with bike-sharing trips.

While dockless bike-sharing has given people a more flexible and inexpensive transport alternative, the dockless design of the system leads to less certainty about the accessibility of a shared bike, which could disrupt users' travel plans and lower trip satisfaction. In addition, dockless systems require more regulations than traditional public bike-sharing schemes. Some negative consequences have already begun to arise in cities, including Beijing and Shanghai. The oversupply and inadequate parking regulation of dockless shared bikes have cluttered sidewalks, bike pathways, and public spaces and blocked people with disabilities from navigating streets, so the bikes often become a public nuisance, jeopardising even non-users' travel satisfaction. Parked dockless shared bikes on the cluttered cycling paths are experienced as obstacles for cyclists and pedestrians, which can result in individuals being forced to seek other and sometimes longer routes. Additionally, insufficient maintenance results in a certain proportion of broken bikes, which can frustrate users as they may need to try several bikes to find a well-functioning bike, further affecting their mood. Therefore, the overall satisfaction of dockless bike-sharing trips is the result of a trade-off between the advantages and disadvantages of the dockless system as experienced by the users (Hernandez, 2017).

As discussed earlier, the combination of using dockless bike-sharing systems and public transit can evoke a considerable change in individuals' transferring behaviours and experiences. In Beijing and Shanghai, more than 90% of the trips that are shorter than 5 km were found to take less time than trips taken by car if completed using a combination of dockless bike-sharing systems and public transport (Mobike Global et al., 2017). Even for trips longer than 5 km, over 20% of the trips in Beijing and 40% of the trips in Shanghai using public transport and shared bikes were suggested to be faster than similar trips by car (Mobike Global et al., 2017). The flexibility and high efficiency of dockless bikes as well as the effort that dockless bike-sharing operating companies make to integrate shared bikes with public transit (such as the higher numbers of bikes available around transit stations or a higher level of relocation schemes to arrange space for dropping off bikes) make bike-sharing systems more convenient, which might increase bike-sharing users' overall travel satisfaction. On the other hand, in terms of non-users who use their own bicycles, or people who simply prefer to walk, the high quantity of dockless shared bikes around public transit stations may hinder their interest in finding a place to park or even to walk across, damaging their impressions of and travel experiences with public transit, further deterring their usage of public transport.

Individuals' transport mode changes induced by the availability of dockless bike-sharing systems could also have wider implications for subjective well-being in a more general sense. First, a mode change can directly affect travel satisfaction, which is a domain-specific life satisfaction that influence subjective well-being (Ettema, Friman, Gärling, & Olsson, 2016). Martin and Shaheen (2014) reported that for commuting, a mode shift from motorised vehicles to active modes is related to a higher level of subjective well-being. Second, an individual's use of time and level of activity participation could be optimised or impaired by a mode change. For example, a switch from public transit to a bike-sharing system may lead to longer travel times, which may limit time for other recreational and social activities. However, one can also make optimised routes that combine necessary activities when travelling using shared bikes and make travel plans that are flexible, thus adding to satisfaction with life. Additionally, a shift from motorised modes to active travel modes has implications for individual and population health. Station-based bike-sharing systems have been found to increase physical activity at the population level (Fishman et al., 2014; Woodcock, Tainio, Cheshire, O'Brien, & Goodman, 2014). Using shared bikes is also claimed to be safer than using privately owned bikes, possibly due to the improved motorists' awareness and careful treatment by the uniformed design of shared bikes and larger groups of cyclists since the introduction of bike-sharing systems (Fishman & Schepers, 2016). These health-related impacts could pose an influence on both physical and subjective well-being. Unfortunately, thus far, there has been no study examining the satisfaction of dockless bike-sharing travel and the implication for subjective well-being.

5.4. Mobility and social exclusion

Social exclusion stresses the disadvantage of being excluded from normal activities in society, and transport-related accessibility problems can be understood as a cause for and a result of social exclusion (Lucas, 2012). A widely cited definition of transport-related social exclusion by Cass, Shove, and Urry (2005) refers to "social-spatial exclusion, or 'access' – by which we mean the ability to negotiate space and time so as to accomplish practices and maintain relations that people take to be necessary for normal social participation" (p. 543). Four key dimensions of access were also identified: financial, physical, organisational and temporal. Lucas (2012) illustrated in her article that the direct and indirect interaction between transport disadvantage and social disadvantage induces transport poverty, which then hinders the accessibility of vital goods, services, and social capitals, resulting in social exclusion outcomes, while social exclusion can, in turn, reinforce transport and social disadvantages, creating a vicious, reinforcing circle of effects.

As a newly developed and rapidly expanding transport mode, dockless bike-sharing systems have the potential to exert an influence on social issues. As with station-based public bike-sharing systems, the convenience, low costs, and flexibility of using dockless shared bikes for short distance trips enable easy trip chaining and may play a beneficial role in reducing transport disadvantages by the provision of a more widely available travel option. Dockless bike-sharing systems could provide an opportunity to extend the activity range and social participation of individuals who experience difficulties in accessing key activities due to a lack of other transport options, thus contributing to their feelings of inclusion in society. The new activities stimulated by dockless shared bikes may create opportunities for individuals to extend or to strengthen their social networks, helping enlarge individuals' social capital. Moreover, the integration of dockless shared bikes with buses and metro systems enlarges the service area of traditional public transit stations such as subway stations, which can, to a certain extent, help people living or working outside the walking range of public transit stations but within cycling distance access these services within their time budget. Despite the scarce empirical knowledge on social exclusion and dockless systems, few studies focusing on general cycling have provided a cornerstone for future works. For example, Martens (2013) found that bikes help the households that are at risk of transport poverty to access certain important destinations.

It is worth noting that transport disadvantage is not exclusively experienced by socially disadvantaged groups (Currie et al., 2010; Currie & Delbosc, 2010; Lucas, 2012; Schwanen et al. 2015). Many people may not have access to public transport before or after working hours, or they face the pressure of punctuality, corresponding to the dimension of temporal access (Cass et al., 2005). In other words, people who are commonly regarded as advantaged (such as those with a decent job or high income) can experience constrained mobility and feel socially excluded because of time poverty for vital activities, especially for some groups such as working women with children (Currie & Delbosc, 2010; Lucas, 2012; Uteng, 2009). As dockless bike-sharing systems are usually 24/7 systems, dockless shared bikes can serve as an extra travel option when public transit is not available. In addition, dockless bike-sharings enable users with low "time sovereignty" to cover longer distances within a fixed period of time when compared to walking, thus helping to improve their travel time ratio and increase their time for activities (Dijst & Vidakovic, 2000).

However, dockless bike-sharing is not a panacea for all groups. The elderly, or those with certain disabilities, can be excluded from benefits of dockless bike-sharing because they have difficulty using the system and can be hindered by cluttered bikes due to their own physical conditions. Furthermore, although the relatively easy sign-up process and easy-to-use smartphone application of the dockless bike-sharing system make the bikes widely accessible for the general public, this can also exclude people who lack smartphones (those who cannot afford smartphones or do not understand how to use them) or online-payment methods from accessing the system.

One of the most important differences between traditional docked bike-sharing systems and dockless bike-sharing systems lies in their impacts on social exclusion in a spatial aspect. Whereas the nature of docked systems defines in advance which areas of a city will be socially included or excluded, dockless bike-sharing systems do not (to the same extent) have this constraint. The flexibility that comes from the dockless nature of the bikes enables operating companies to adjust the situation by setting new plans about the designated operating areas, the organisation of bike volumes in different areas and the redistribution of shared bikes. However, this benefit of dockless systems also means that providers may not strive for an even distribution across the city and may want to focus on wealthier, more popular or denser areas, which may, in turn, aggravate the existing exclusion of the marginalised areas. Therefore, research into the relationships between social exclusion, mobility and dockless bike-sharing systems is needed to shed light on whether these systems have resulted in social changes and, if there have been any changes, whether the systems have improved or reinforced the existing exclusion of certain social groups or geographic areas.

5.5. The equity of dockless bike-sharing access

Dockless bike-sharing systems are expanding their markets across China and have become highly popular in the cities in which they operate. Despite the large number of shared bikes, it is important to take into account whether these systems promote the equity of bike-sharing access to all potential users, including those disadvantaged groups with limitations in approaching other transport modes (such as public transport and automobiles).

Studies on docked bike-sharing systems have revealed a lower access to the service among traditionally disadvantaged groups (e.g. Hosford & Winters, 2018). Although to the authors' knowledge there are few empirical studies on whether individuals across all social spectrums have equal access to dockless bike-sharing systems thus far, concerns have been raised that dockless bike-sharing systems have (un)intentionally targeted to specific areas or socio-demographical groups. As the deregulation and uncertainty of dockless bike-sharing systems lead to the appearance of shared bikes in more relatively remote areas, many operating companies (e.g. Lime, Mobike) have used geofencing to set up their own designated operating areas in which users can pick up and drop off bicycles for better management (Zhang, 2018). Therefore, the spatial equality of dockless bike-sharing services relies also on the consideration of operating areas, similar to docked bike-sharing schemes whose equal access in divergent areas falls largely on the shoulders of the pre-site selection of dock locations. Although the operating areas in one city for different dockless bike-sharing companies can vary, this strategy can still contribute to an unequal accessibility of dockless shared bikes inside and outside the operating areas. However, compared with the placement of new docking stations for docked systems, dockless bike-sharing have the benefit of feasibly update the designated operating areas in their mobile application backend system.

As discussed, the venture capital funding of dockless bike-sharing systems often results in a large number of shared bike operators providing a similar service within a given area (Gu et al., 2019). The saved expenditure for dockless bike-sharing systems on building docking stations ensures a lower cost per bike, allowing users to have more access per capita compared to docked systems. On the one hand, the large amount of available bikes in the systems might be adequate to achieve a baseline for universal access (Mooney et al., 2019). On the other hand, however, the "privatization" of the system can result in increased segregation between "hot" zones, where the users are concentrated and the demand is high, and "cold" spaces such as suburbs or peripheral areas, thus resembling the organisation of some public transport companies (Jaramillo, Lizárraga, & Grindlay, 2012). Thus, the redistribution of dockless shared bikes among the "hot" and "cold" zones within the operating areas can be important for reaching an equal access to shared bikes. However, there is currently a general lack of appropriate redistribution efforts by private operators, with bikes sometimes inundating popular areas in cities (Shi et al., 2018; Spinney & Lin, 2018).

Allowing the concentration of dockless shared bikes in popular areas with highly dense populations fits the business model of attracting as many users as possible. However, this approach of allocating bikes could raise the unintentional social consequence of limiting the accessibility of shared bikes for groups who are already experiencing social disadvantages or limitations of other transport modes. This might result in what Graham and Marvin (2001) mention in their book as "a splintering urbanism", wherein the travel-rich will have a generally smart-technology rich environment with good travel options while the travel-poor will benefit much less and continue to face limited transport choices. Therefore, the underserved population may be marginalised from the full benefits of dockless bike-sharing schemes, such as increased physical activity and social participation, as well as from sharing the profits of existing and future active travel-oriented planning efforts, further peripheralizing the disadvantaged groups and enlarging their exclusion in society.

6. Future research priorities

The recent growth of dockless bike-sharing systems in China and rapid worldwide adoption of similar systems has resulted in a considerable gap in the relevant research. This article reviewed existing studies on the implications of dockless bike-sharing systems for users. By comparing dockless bike-sharing systems with station-based bike-sharing schemes, the authors discussed what the distinctive characteristics of dockless bike-sharing mean for travel patterns, travel experiences, and relevant social impacts. Based on this review a number of critical future study priorities has been identified.

First, there is insufficient knowledge about the travel behaviour of dockless bike-share users and the relationships between different transport modes. The scarce evidence that does exist has suggested that dockless bike-sharing systems were mostly active around bus stops and metro stations and able to extend the transfer radius of public transit. Whether and to what extent the new dockless bike-sharing service compensate or substitute transit use and walking, and how effective this system reduces car usage require future evaluations. Second, only limited studies have explored how the travel behaviour of dockless bike-sharing users diverge according to individuals' socio-demographics and built environment. Dockless bike-sharing systems are suggested to be more popular among young or middle-aged groups. A higher usage rates of dockless bike-sharing is also found to be related to a more supportive environment for cycling. What effects the social environment and attitude attributes has on the usage of dockless shared bikes remain under researched. Dedicated dockless bike-sharing surveys among users and non-users could be applied to access the relationship between travel attitudes, the acceptance of the new systems and the usage of dockless systems. More studies addressing issues related to behavioural responses to dockless bike-sharing and their determinants can help enhance our understanding of the underlying mechanisms why mobility patterns of dockless bike-sharing users differs from cities.

As a newly developed transport mode, the travel experiences and the impacts of the system are of critical importance but remain a limited researched area. Accordingly, scholars should focus their attention on better understand the relationship between transport equity and access to dockless shared-bikes. Based on the existing research on docked bike-sharing systems and general cycling, this review speculates possible implications that the distinctive characteristics of dockless bike-sharing systems could have on users in terms of the travel satisfaction, subjective well-being and social exclusion. Further researches are expected to empirically test these hypothesises. More research of this field can help draw bike-sharing users across the social spectrum, contributing to the fairness of this system and social equality. As uncertainty and availability become important potential issues for the users and operators of dockless bike share systems, researchers must confront the challenge of developing standard and justifiable tools to calculate accessibility measures or predictive mode choice models in places where dockless shared bikes can be parked freely around the city. The massive geographic datasets derived from GPS information can encompass high-valued trajectory records of the same user on different dates and times, which provides a cornerstone for the development of a route choice model for dockless bike-sharing riding.

7. Conclusion and discussion

Dockless bike-sharing systems have emerged in many cities as a transport option which can influence people's activity and travel behaviour, contributing to social consequences such as social exclusion, social equity and subjective well-being, etc. This spectrum of issues related to dockless bike-sharing systems has not yet been fully examined by the research community.

This paper captures several critical themes through a review of recent pertinent literature. First, the dockless design of a bike-sharing system could improve users' experiences at the end of their trips compared with docked systems. The authors hypothesise that the flexibility and efficiency of dockless bike-sharing systems strongly connects the mode to public transit. In addition, the overall trip satisfaction of dockless bike-share users will be the result of the trade-offs between the advantages and disadvantages of dockless systems experienced by the users. The availability and usage rates of dockless bike-sharing systems can also have an implication on an individual's subjective well-being by influencing his/her satisfaction with travel experience, health and social participation. In addition, the nature of the dockless system is likely to reduce social exclusion within the dockless zone. However, the relationship between social exclusion and access to dockless shared bikes requires additional research since the popularity and presence of these systems is increasing in cities around the world.

One essential benefit of dockless bike-sharing systems is the unprecedented collection of large-scale riding trajectory data from the imbedded GPS device. Although the large-scale trip trajectory data makes it possible for scholars to analyse cyclists' travel behaviour in new ways, researchers are often faced with the dilemma that the vast majority of the privately operating dockless bike-sharing companies do not publicly share the data. For docked bike-sharing systems, the usage data are often owned by the local government as they usually subsidise and organise the services. Instead, the data for dockless bike-sharing systems are increasing privatised. The operators regard it as a commodity rather than a public resource that could enable users and cities to gain benefits from city movements and infrastructure planning (Gössling, 2018; Spinney & Lin, 2018). Some of the operating companies (such as Mobike, Lime) claimed to share the data with government departments and scientific research institutions for the refinement and intelligent management of shared bicycles when ensuring user privacy and data security (e.g. Mobike Global et al., 2018). However, Spinney and Lin (2018) suggested that the privately operating companies attempted to use the data as a leverage to shape a more unequal relationship with the governments rather than a shared partnership. That is, instead of sharing the usage data with municipalities to help improve bicycle planning, the operators often intend to use the data to negotiate with city governments in order to improve their own business and brand profile.

When dockless bike-sharing systems benefit the short distance trips of local residences and travellers, issues of vandalism and irregular parking occur with the rapid expansion of shared bikes. Local governments have implemented different initiatives based on trade-offs. For example, in August, 2018, Amsterdam temporarily removed all dockless shared bikes from the city's streets, while in Hong Kong, a code of practice was implemented in September 2018 to encourage sustainable self-regulation (Transport Department, 2018). Singapore, instead, chose to embrace dockless bike-sharing as part of its transport ecosystem (Lim, 2018). In the origin city of dockless bike-sharing system, the Beijing Municipal Transportation Commission has changed their attitudes from encouraging to restricting the volume of shared bikes in the city (Gu et al., 2019). Additionally, considering the deregulated nature of dockless bike-sharing systems, the geofencing (or electric fencing) by guiding users to park bikes in designated zones has been implemented by local government and main dockless bike-sharing operators in many Chinese cities (Zhang, Lin, & Mi, 2019). A better knowledge on the influences of various responses of cities, especially the geofencing policy, can provide implications and suggestions for cities to facilitate the benefits and alleviate the challenges of dockless bike-sharing systems on urban daily travel and social implications such as inclusion in the society and equity.

Technological innovation has been gradually incorporated in the transport systems and contributed to a considerable change in the ways of owning and using all kinds of vehicles in recent years. Attention has been paid to the efficiency and cohesion on the organisation of the systems, or the business models how the systems are operated. However, analysis of the users' perspectives is crucial to understand the sustainability and acceptance of the innovation. As a product of technological innovation in transport, dockless bike-sharing has often been questioned in terms of the sustainability of its business model and system operation. However, an examination of this system from the users' perspectives presents distinctive insights on the reasons why the system is loved by users, the problems the systems have in the accessibility and distribution, and the social benefits and issues the system raised and have the potential to advance. In the context of the shared-economy, technological innovation in transport has brought more other dockless new mobility and non-bike shared micro-mobility, such as the scooter-sharing systems. Some of the similar issues and social implications discussed in dockless bike-sharing systems could also be relevant. Scooter-sharing systems encompass the same advantages of flexibility and efficiency for short distance trips, while also confronting the challenges of uncertainty related to access and the deregulated nature in organisation. But the issues caused by irregular parking behaviour could be less severe due to the currently smaller operating scales. These advantages and disadvantages of scooter-sharing systems can likewise alert an influence on users' travel experiences, exclusion and equity in society. In many cities, these different forms of micro-mobility present similar opportunities and challenges as dockless bike-sharing systems do today.

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References

Ai, Y., Li, Z., & Gan, M. (2018). A solution to measure traveler's transfer tolerance for walking mode and dockless bike-sharing mode. *The Journal of Supercomputing*, *75*(6), 3140–3157.

Bao, J., He, T., Ruan, S., Li, Y., & Zheng, Y. (2017). Planning bike lanes based on sharing-bikes' trajectories. In *Proceedings of the 23rd ACM SIGKDD international conference on knowledge discovery and data mining* (pp. 1377–1386). ACM.

Buck, D., & Buehler, R. (2012). Bike lanes and other determinants of capital bikeshare trips. Paper presented at the Transportation Research Board Annual Meeting 2012, Washington, DC. Conference paper. Retrieved from https://nacto.org/wp-content/uploads/2012/02/Bike-Lanes-and-Other-Determinants-of-Capital-Bikeshare-Trips-Buck-et-al-12-3539.pdf

Buck, D., Buehler, R., Happ, P., Rawls, B., Chung, P., & Borecki, N. (2013). Are bikeshare users different from regular cyclists? *Transportation Research Record: Journal of the Transportation Research Board*, *2387*, 112–119.

Cass, N., Shove, E., & Urry, J. (2005). Social exclusion, mobility and access. *The Sociological Review*, *53*(3), 539–555.

Chang, S., Song, R., He, S., & Qiu, G. (2018). Innovative bike-sharing in China: Solving faulty bike-sharing recycling problem. *Journal of Advanced Transportation*, *2018*, 1–10.

Currie, G., & Delbosc, A. (2010). Modelling the social and psychological impacts of transport disadvantage. *Transportation*, *37*(6), 953–966.

Currie, G., Richardson, T., Smyth, P., Vella-Brodrick, D., Hine, J., Lucas, K., … Stanley, J. K. (2010). Investigating links between transport disadvantage, social exclusion and well-being in Melbourne – updated results. *Research in Transportation Economics*, *29*(1), 287–295.

Damant-Sirois, G., & El-Geneidy, A. M. (2015). Who cycles more? Determining cycling frequency through a segmentation approach in Montreal, Canada. *Transportation Research Part A: Policy and Practice*, *77*, 113–125.

de Geus, B., De Bourdeaudhuij, I., Jannes, C., & Meeusen, R. (2008). Psychosocial and environmental factors associated with cycling for transport among a working population. *Health Education Research*, *23*(4), 697–708.

DeMaio. (2009). Bike-sharing: History, impacts, models of provision, and future. *Journal of Public Transportation*, *12*(4), 3.

Dijst, M., & Vidakovic, V. (2000). Travel time ratio: The key factor of spatial reach. *Transportation*, *27*(2), 179–199.

Du, M., & Cheng, L. (2018). Better understanding the characteristics and influential factors of different travel patterns in free-floating bike sharing: Evidence from Nanjing, China. *Sustainability*, *10*(4), 1244.

Ekkekakis, P., Hall, E. E., & Petruzzello, S. J. (2008). The relationship between exercise intensity and affective responses demystified: To crack the 40-year-old nut, replace the 40-year-old nutcracker!. *Annals of Behavioral Medicine*, *35*(2), 136–149.

Ettema, D., Friman, M., Gärling, T., & Olsson, L. E. (2016). Travel mode use, travel mode shift and subjective well-being: Overview of theories, empirical findings and policy implications. In D. Wang & S. He (Eds.), *Mobility, sociability and well-being of urban living* (pp. 129–150). Berlin: Springer.

Ettema, D., & Schekkerman, M. (2016). How do spatial characteristics influence well-being and mental health? Comparing the effect of objective and subjective characteristics at different spatial scales. *Travel Behaviour and Society*, *5*, 56–67. doi:10.1016/j.tbs.2015.11.001

Ettema, D., & Smajic, I. (2015). Walking, places and wellbeing. *The Geographical Journal*, *181*(2), 102–109.

Faghih-Imani, A., & Eluru, N. (2015). Analysing bicycle-sharing system user destination choice preferences: Chicago's Divvy system. *Journal of Transport Geography*, *44*, 53–64.

Faghih-Imani, A., & Eluru, N. (2016). Incorporating the impact of spatio-temporal interactions on bicycle sharing system demand: A case study of New York CitiBike system. *Journal of Transport Geography*, *54*, 218–227.

Faghih-Imani, A., Eluru, N., El-Geneidy, A. M., Rabbat, M., & Haq, U. (2014). How land-use and urban form impact bicycle flows: evidence from the bicycle-sharing system (BIXI) in Montreal. *Journal of Transport Geography*, *41*, 306–314.

Fernández-Heredia, Á, Monzón, A., & Jara-Díaz, S. (2014). Understanding cyclists' perceptions, keys for a successful bicycle promotion. *Transportation Research Part A: Policy and Practice*, *63*, 1–11.

Fishman, E. (2015). Bikeshare: A review of recent literature. *Transport Reviews*, *36*(1), 92–113.

Fishman, E., & Schepers, P. (2016). Global bike share: What the data tells us about road safety. *Journal of Safety Research*, *56*, 41–45. doi:10.1016/j.jsr.2015.11.007

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

Fishman, E., Washington, S., & Haworth, N. (2014). Bike share's impact on car use: Evidence from the United States, Great Britain, and Australia. *Transportation Research Part D: Transport and Environment*, *31*, 13–20.

Fishman, E., Washington, S., Haworth, N., & Mazzei, A. (2014). Barriers to bikesharing: An analysis from Melbourne and Brisbane. *Journal of Transport Geography*, *41*, 325–337.

Fishman, E., Washington, S., Haworth, N., & Watson, A. (2015). Factors influencing bike share membership: An analysis of Melbourne and Brisbane. *Transportation Research Part A: Policy and Practice*, *71*, 17–30.

Fuller, D., Gauvin, L., Kestens, Y., Daniel, M., Fournier, M., Morency, P., & Drouin, L. (2011). Use of a new public bicycle share program in Montreal, Canada. *American Journal of Preventive Medicine*, *41*(1), 80–83.

Gatersleben, B., & Uzzell, D. (2007). Affective appraisals of the daily commute: Comparing perceptions of drivers, cyclists, walkers, and users of public transport. *Environment and Behavior*, *39*(3), 416–431.

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.

Gössling, S. (2018). ICT and transport behavior: A conceptual review. *International Journal of Sustainable Transportation*, *12*(3), 153–164.

Graham, S., & Marvin, S. (2001). *Splintering urbanism: Networked infrastructures, technological mobilities and the urban condition*. London: Routledge.

Gu, T., Kim, I., & Currie, G. (2019). To be or not to be dockless: Empirical analysis of dockless bikeshare development in China. *Transportation Research Part A: Policy and Practice*, *119*, 122–147.

Handy, S. L., Xing, Y., & Buehler, T. J. (2010). Factors associated with bicycle ownership and use: A study of six small US cities. *Transportation*, *37*(6), 967–985.

Heinen, E., Kamruzzaman, M., & Turrell, G. (2018). The public bicycle-sharing scheme in Brisbane, Australia: Evaluating the influence of its introduction on changes in time spent cycling amongst a middle-and older-age population. *Journal of Transport & Health*, *10*, 56–73.

Heinen, E., Maat, K., & van Wee, B. (2011). The role of attitudes toward characteristics of bicycle commuting on the choice to cycle to work over various distances. *Transportation Research Part D: Transport and Environment*, *16*(2), 102–109.

Heinen, E., Maat, K., & van Wee, B. (2012). The effect of work-related factors on the bicycle commute mode choice in the Netherlands. *Transportation*, *40*(1), 23–43.

Heinen, E., van Wee, B., & Maat, K. (2010). Commuting by bicycle: An overview of the literature. *Transport Reviews*, *30*(1), 59–96.

Hernandez, J. C. (2017, September 2). As bike-sharing brings out bad manners, China asks, what's wrong with us? *The New York Times*. Retrieved from https://www.nytimes.com/2017/09/02/world/asia/china-beijing-dockless-bikeshare.html

Hosford, K., & Winters, M. (2018). Who are public bicycle share programs serving? An evaluation of the equity of spatial access to bicycle share service areas in Canadian cities. *Transportation Research Record: Journal of the Transportation Research Board*. doi:10.0361198118783107.

Jäppinen, S., Toivonen, T., & Salonen, M. (2013). Modelling the potential effect of shared bicycles on public transport travel times in Greater Helsinki: An open data approach. *Applied Geography*, *43*, 13–24.

Jaramillo, C., Lizárraga, C., & Grindlay, A. L. (2012). Spatial disparity in transport social needs and public transport provision in Santiago de Cali (Colombia). *Journal of Transport Geography*, *24*, 340–357.

Lierop, D. v., Badami, M. G., & El-Geneidy, A. M. (2018). What influences satisfaction and loyalty in public transport A review of the literature. *Transport Reviews*, *38*(1), 52–72.

Lim, A. (2018, March). Shared-bicycle operators to be licensed to curb indiscriminate parking. *The Straits Times*. Retreived from https://www.straitstimes.com/singapore/transport/shared-bicycle-operators-to-be-licensed-to-curb-indiscriminate-parking

Lucas, K. (2012). Transport and social exclusion: Where are we now? *Transport Policy*, *20*, 105–113.

Mao, Z., Ettema, D., & Dijst, M. (2016). Commuting trip satisfaction in Beijing: Exploring the influence of multimodal behavior and modal flexibility. *Transportation Research Part A: Policy and Practice*, *94*, 592–603.

Martens, K. (2013). Role of the bicycle in the limitation of transport poverty in the Netherlands. *Transportation Research Record: Journal of the Transportation Research Board*, *2387*, 20–25.

Martin, E. W., & Shaheen, S. A. (2014). Evaluating public transit modal shift dynamics in response to bikesharing: A tale of two U.S. Cities. *Journal of Transport Geography*, *41*, 315–324.

Mobike Global, Beijing Tsinghua Tongheng Planning and Design Institute, & China New Urbanization Research Institute. (2017, May 19). The Mobike white paper: Bike-share in the city. Retrieved from https://mobike.com/sg/blog/post/mobikewhitepaper

Mooney, S. J., Hosford, K., Howe, B., Yan, A., Winters, M., Bassok, A., & Hirsch, J. A. (2019). Freedom from the station: Spatial equity in access to dockless bike share. *Journal of Transport Geography*, *74*, 91–96.

Murphy, E., & Usher, J. (2014). The role of bicycle-sharing in the city: Analysis of the Irish experience. *International Journal of Sustainable Transportation*, *9*(2), 116–125.

Ogilvie, F., & Goodman, A. (2012). Inequalities in usage of a public bicycle sharing scheme: Socio-demographic predictors of uptake and usage of the London (UK) cycle hire scheme. *Preventive Medicine*, *55*(1), 40–45.

Parkes, S. D., Marsden, G., Shaheen, S. A., & Cohen, A. P. (2013). Understanding the diffusion of public bikesharing systems: Evidence from Europe and North America. *Journal of Transport Geography*, *31*, 94–103.

Ricci, M. (2015). Bike sharing: A review of evidence on impacts and processes of implementation and operation. *Research in Transportation Business & Management*, *15*, 28–38.

Rixey, R. A. (2013). Station-level forecasting of bikesharing ridership: Station network effects in three US systems. *Transportation Research Record*, *2387*(1), 46–55.

Schwanen, T., Lucas, K., Akyelken, N., Cisternas Solsona, D., Carrasco, J.-A., & Neutens, T. (2015). Rethinking the links between social exclusion and transport disadvantage through the lens of social capital. *Transportation Research Part A: Policy and Practice*, *74*, 123–135.

Shaheen, S., Cohen, A., & Martin, E. (2013). Public bikesharing in North America: Early operator understanding and emerging trends. *Transportation Research Record: Journal of the Transportation Research Board*, *2387*(1), 83–92.

Shaheen, S., Guzman, S., & Zhang, H. (2010). Bikesharing in Europe, the Americas, and Asia: Past, present, and future. *Transportation Research Record*, *2143*(1), 159–167.

Shaheen, S., Martin, E., & Cohen, A. (2013). Public Bikesharing and modal shift behavior: A comparative study of early bikesharing systems in North America. *International Journal of Transportation*, *1*(1), 35–54.

Shaheen, S., Zhang, H., Martin, E., & Guzman, S. (2011). Hangzhou public bicycle: Understanding early adoption and behavioral response to bikesharing in Hangzhou, China. *Transportation Research Record*, *2247*(1), 33–41.

Shen, Y., Zhang, X., & Zhao, J. (2018). Understanding the usage of dockless bike sharing in Singapore. *International Journal of Sustainable Transportation*, *12*(9), 686–700.

Shi, J. G., Si, H., Wu, G., Su, Y., & Lan, J. (2018). Critical factors to achieve dockless bike-sharing sustainability in China: A stakeholder-oriented network perspective. *Sustainability*, *10*(6), 2090.

Spinney, J., & Lin, W.-I. (2018). Are you being shared? Mobility, data and social relations in Shanghai's public bike sharing 2.0 sector. *Applied Mobilities*, *3*(1), 66–83.

St-Louis, E., Manaugh, K., van Lierop, D., & El-Geneidy, A. (2014). The happy commuter: A comparison of commuter satisfaction across modes. *Transportation Research Part F: Traffic Psychology and Behaviour*, *26*, 160–170.

State Information Centre. (2017, September 13). The research report on bike-sharing employment. Retrieved from http://www.sic.gov.cn/News/568/8452.htm

Titze, S., Stronegger, W. J., Janschitz, S., & Oja, P. (2008). Association of built-environment, social-environment and personal factors with bicycling as a mode of transportation among Austrian city dwellers. *Preventive Medicine*, *47*(3), 252–259.

Transport Department. (2018, September). *Code of Practice (CoP) for automated dockless bicycle rental services*. Retrieved from https://www.td.gov.hk/mini_site/cic/files/others/code_of_practice_en.pdf

Ursaki, J., & Aultman-Hall, L. (2016). *Quantifying the equity of bikeshare access in US cities*. Paper presented at the 94th annual meeting of the Transportation Research Board, Washington, DC.

Uteng, T. P. (2009). Gender, Ethnicity, and constrained mobility: Insights into the resultant social exclusion. *Environment and Planning A*, *41*(5), 1055–1071.

Van Lierop, D., Grimsrud, M., & El-Geneidy, A. (2015). Breaking into bicycle theft: Insights from Montreal, Canada. *International Journal of Sustainable Transportation*, *9*(7), 490–501.

WHO. (2016). *Global recommendations on physical activity for health*. Geneva: World Health Organization; 2010.

Woodcock, J., Tainio, M., Cheshire, J., O'Brien, O., & Goodman, A. (2014). Health effects of the London bicycle sharing system: Health impact modelling study. *BMJ*, *348*, g425.

Xing, Y., Handy, S. L., & Mokhtarian, P. L. (2010). Factors associated with proportions and miles of bicycling for transportation and recreation in six small US cities. *Transportation Research Part D: Transport and Environment*, *15*(2), 73–81.

Zhang, Y. (2018, July). Dockless bike share: How to get the most out of it? Retrieved from https://ecomobility.org/dockless-bike-share/

Zhang, Y., Lin, D., & Mi, Z. (2019). Electric fence planning for dockless bike-sharing services. *Journal of Cleaner Production*, *206*, 383–393.

Zhang, H., Shaheen, S. A., & Chen, X. (2014). Bicycle evolution in China: From the 1900s to the present. *International Journal of Sustainable Transportation*, *8*(5), 317–335.

Zhao, J., Wang, J., & Deng, W. (2015). Exploring bikesharing travel time and trip chain by gender and day of the week. *Transportation Research Part C: Emerging Technologies*, *58*, 251–264.