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HOW DOCKLESS BIKE-SHARING CHANGES LIVES: AN ANALYSIS OF CHINESE CITIES

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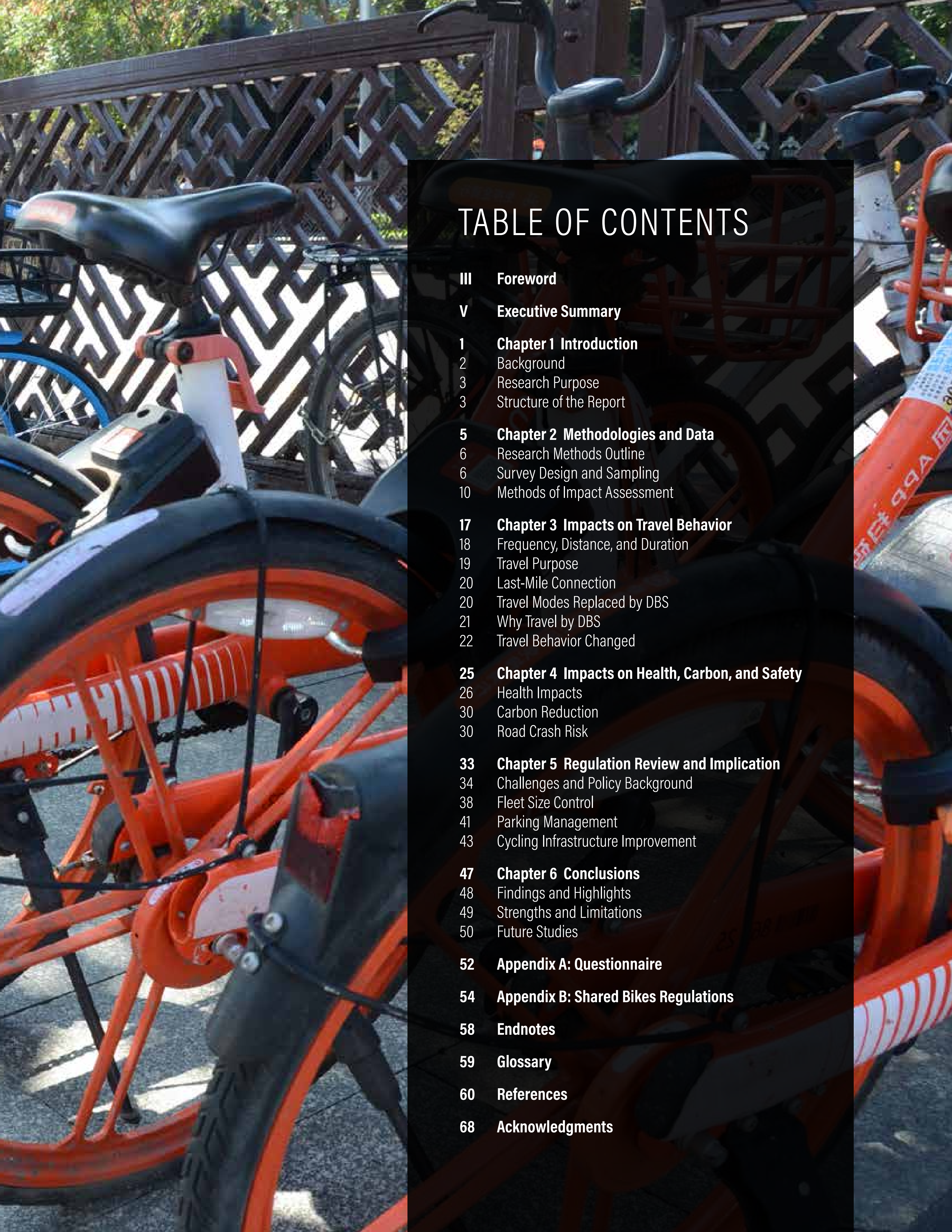

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FOREWORD

Dockless bike-sharing (DBS) is one of the most popular shared transport systems to impact people's lives in recent years. Since its rapid proliferation on city streets across the globe in 2016, DBS companies have had a tumultuous journey navigating, on the one hand, an explosion in demand, and on the other, significant regulatory hurdles and negative perceptions. As many of these companies enter their fifth year of operations, their global footprint has decreased, but their relevance in Asian cities has grown. As of 2019, DBS systems supported millions of short trips and connections to public transit in over 360 Chinese cities. The shift to low-emission modes and increased physical activity of DBS users are the most significant co-benefits of the system. However, these systems can also pose challenges to the management of public space if regulations are not based on assessments of their impact, and if they are not well integrated into the transport ecosystem.

By studying DBS systems in 12 Chinese cities, this report offers concrete evidence of how DBS changes people's daily lives and points to an emerging philosophy of urban management and the role of the public and private sectors in ensuring sustainable and equitable outcomes through transport services. The authors investigated how the system changes people's travel behavior, assessed the benefits or risks on public health, carbon emissions, and road safety, and showcased good management practices. The authors also recommend that cities should improve DBS management by setting up key performance indicators for operators, clarifying rules for parking management, providing safer cycling facilities, and encouraging standardized technologies.

At the time of this report's publication, severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) continues to spread globally, causing more than 11.63 million cases and 538,529 deaths[1] (JHU July 7, 2020). Admittedly, SARS-CoV-2 has changed the global landscape forever, and its impact on urban life will be long-lasting. During the peak of the crisis, bicycles served as one of the few resilient and safe ways in which citizens could move around for essential needs. As cities begin to reopen and social connection recovers, transport culture might shift from centralized motorized modes to distributed customized solutions. And while Beijing has seen a 150 percent increase in use of bike-sharing systems (Xinhua News 2020),[2] it is unclear whether cycling and walking will become a new normal of daily travel or whether the increase is just a temporary response to the pandemic. The answer will lie in the shift in public mindsets, good built-environments and urban management, and responsible and financially healthy operators.

DBS systems must be welcomed as an effective mechanism for cities looking to rebuild their economies, ensure public health, and reduce their emissions. While circumstances may differ, stories and lessons from Chinese cities can provide insights and good practice for cities elsewhere on how to build a cycling culture and encourage bike-sharing. Scaling up the bike-sharing culture with innovative solutions also requires collaborations among networks of global and local communities. That is what the World Resources Institute (WRI) and the New Urban Mobility (NUMO) alliance are doing now for cities around the world.

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EXECUTIVE SUMMARY

HIGHLIGHTS

- Dockless bike-sharing (DBS) systems have expanded rapidly in China since 2016. By the end of 2019, they had served over 360 Chinese cities. As the alternative mode of short-distance travel that also connects to public transit, the systems bring convenience and meet citizens' travel demands.
- This report aims to investigate how DBS changes people's travel behavior and assesses its impacts on public health, carbon emissions, road safety, and urban management in 12 Chinese cities.
- The impact assessment findings show that people can obtain more health benefits and emit less carbon emissions by using DBS over motorized travel. Yet, DBS users, like other cyclists, are vulnerable compared with those using motorized vehicles.
- This report also reviews DBS policies, and showcases good practices in the 12 study cities that could provide useful references for other cities intending to adopt DBS systems.
- To better regulate the DBS as a short-distance travel mode, cities could improve DBS management by introducing innovative policies and measures, such as setting up key performance indicators (KPIs) for operators, clarifying rules for parking management, providing safer cycling facilities, and encouraging standardized technologies.

Background

There is a boom in dockless bike-sharing (DBS) systems in world cities. As an alternative and innovative trip mode, DBS systems have been implemented in hundreds of cities around the world. Since 2016, DBS has expanded rapidly in China, which is the largest global market of DBS. The number of DBS bikes in China was estimated at 23 million in 2017, operating in over 200 Chinese cities (CAICT 2019; State Information Center 2018). Although the fleet dropped to 19.5 million in late 2019, the DBS service had expanded operations to over 360 Chinese cities. Users can use mobile phones to locate, unlock, and use bikes with convenience. The added accessibility has fulfilled huge travel demand in cities, and has been a factor in shifting the paradigm away from personal car ownership and toward an urban mobility characterized by a more integrated seamless transport system.

Benefits and issues. DBS has rapidly changed the transport ecosystem in pursuit of the development of a personal and convenient commute—typically catering to first/last-mile connectivity. However, the oversaturated market resulted in increases in fleet sizes, vandalism, clutter, and curbing pedestrian space. Those challenges created debates while introducing DBS into cities. In addition, there is a lack of nationwide research and analysis on the impacts of dockless shared bikes on travel behavior change, public health, carbon emissions, road safety, and the urban environment.

About This Report

This report assesses multiple impacts of DBS (specifically, fully human-powered bikes) on Chinese cities, investigates cities' regulatory responses, and identifies best practices on DBS systems management. The implications could be a useful reference for cities introducing DBS systems. The report answers three major questions:

- **Question 1:** Has DBS changed people's travel behavior? If so, how has it shifted people from other transport modes?
- **Question 2:** What are the health, carbon, and safety impacts (positive and negative) of DBS?

- **Question 3:** What can cities learn to improve DBS regulations?

Multiple methods applied to assess the impacts of DBS. To answer the questions above, we combined the DBS user experience survey with a large amount of literature review. We conducted the DBS survey in 12 Chinese cities, encompassing 8,218 valid responses. For the DBS impact assessment, we adopted methodologies such as health impact assessment, carbon inventory estimation, and road safety assessment from a wide range of global literature. We have also reviewed over 60 relevant Chinese regulations and case studies to support our discussion of policy implications and the conclusions we reach.

The report aims to reach three groups of audiences. Cities will have good knowledge of the benefits of introducing similar solutions and work more effectively with users and operators toward an integrated and healthy transport system for all. Decision-makers can refer to impact results from the study to guide the city's relevant investment decisions or adopt the recommended regulations to better manage the DBS fleet, parking, and facilities, promoting more sustainable modes of transport and maintaining urban built-environments. The general public can maximize the health benefits by adjusting their cycling duration and intensity based on the recommendations. Finally, academic communities can use the results to enrich existing studies and comparative findings from across the globe.

DBS Impacts

This report investigates how DBS has impacted cities after the service was introduced. It provides the quantitative impacts of DBS in 12 Chinese cities on travel behavior change, public health, emissions mitigation, and road safety.

Travel behavior change:

- Despite large geographical and socioeconomic differences, the results show that DBS has a homogenous impact on travel behavior change among the 12 studied cities.

- The findings indicate that DBS increased connectivity to other modes of transport, **54 percent** of respondents used DBS to connect to other modes, from which, **91 percent** of the linking trips were used to access public transport.
- Depending on the city, **17—45 percent** of total dockless bike-sharing kilometers traveled replaced motorized kilometers traveled (including private cars, taxis, ride-hailing, and motorcycles).

Health impact:

- Based on this research, the health benefit from DBS cycling outweighs the risk from exposure to polluted air while cycling; therefore, cycling should be further encouraged. The net mortality avoided annually among 235 million Chinese DBS users would be **59,635** (95% CI 33,181–90,142).
- For most Chinese cities with the average $PM_{2.5}$ concentration within 50–60μg/m^3, **one-hour of cycling per day could reach the maximum health benefit.** Cycling more than 30 minutes per day at a $PM_{2.5}$ level above 160μg/m^3 is not recommended.

Carbon mitigation impact:

- DBS could reduce total CO_2 by **4.8 million tonnes** annually,[3] due to kilometers avoided from private motorized modes. However, emission reduction is not as large as expected because most replaced trips are short-distance (first/last mile) and were previously completed by walking and public transport.

Safety impact:

- The perceived safety was generally low among DBS users in the 12 cities. Only 7 percent of respondents reported feeling safe while cycling. The built-environment for cyclists is not improving fast enough to accommodate surging DBS usage.
- Neither released survey results nor academic or commercial studies in China have quantified the road safety risk difference between using DBS versus other types of bikes. Therefore, among total bike fatalities in China in 2018 (20,751), our analysis attributed **15,556** (95% CI 14,669–16,443) to DBS, more than half of the total, based on its significant share of total cycling mileage.

Policy Implications

Lessons from DBS management in Chinese cities could serve as useful reference points for other cities that plan to adopt DBS systems. As these systems are widely adopted and used in China, local governments have experience in improving DBS management to enable a better built-environment and promote DBS as a sustainable solution.

Some implications of relevant regulation and management are as follows:

- **Fleet size management.** Overall, cities evolved from a laissez-faire approach to proactive regulation on fleet size by capping the DBS fleet number with stringent management measures. Yet cities still need to develop scientifically based methodologies to estimate the total DBS fleet and design incentive schemes for DBS operators to encourage DBS as a green and healthy transport mode.
- **Performance-based evaluation.** Setting up a KPI system to determine permit renewal/ter-

mination based on operators' performance not only allows the public sector to have a strong regulatory framework on fleet size management but also gives a strong incentive for operators to provide quality service.

- **Regulated parking.** Cities should set up DBS parking design standards, creating clear rules on how curb space should be used, especially at critical locations like intersections, public transit stations, schools, etc.
- **Standardized technologies.** To enable users to better follow the rules, cities should encourage standardized technology applications on parking management, since these could enhance the efficiency of parking management and save time and effort for both the public sector workforce and operators.
- **Dedicated cycling facilities and safety design.** Cities should introduce DBS with more dedicated cycling infrastructures and with higher safety design standards to improve accessibility of cycling as a preferred sustainable transport mode, by upgrading the Comprehensive Transport Plan, Non-motorized Transport Plan, and Street Standards.
- **Road safety awareness and targeted education.** Road safety awareness and targeted education should focus more on enabling a safer and healthier cycling environment.

Future Study

In the future, we will improve this study by conducting more sample surveys and continuous policy reviews. We will also select some pilot cities to carry out the following in-depth studies: (1) monetizing DBS cycling's net impact on health, climate, and the social economy; (2) assessing the overall disease burden avoided in terms of disability-adjusted life years; (3) assessing the impact breakdown by age, sex, type of disease, and other indicators such as equity and public service accessibility; (4) providing detailed and customized policy recommendations or solutions.

CHAPTER 1

INTRODUCTION

In less than five years, dockless bike-sharing (DBS) systems have experienced exponential growth in China, expanding services to more than 360 cities with an average daily trip reaching 47 million traveled kilometers. Meanwhile, poorly managed DBS fleets bring chaos to cities, encroaching on walking space and blocking transit station entrances. A comprehensive nationwide impact analysis of DBS should be further investigated to support the decision-making of relevant stakeholders, especially on travel behavior change, public health, emissions, road safety, and urban management.

1.1 Background

Dockless shared bikes in Chinese cities

Shared micro-mobility encompasses all shared-use fleets of small, partially, or fully human-powered vehicles such as bikes, e-bikes, and e-scooters[4] (NACTO 2018). It has rapidly changed transport systems globally by furthering development of the personal and convenient commute—typically catering to first/last-mile connectivity. Solutions have diversified in different geographies. The United States and Europe have quickly adopted e-scooters as their preferred vehicles since 2018.

In China, dockless bike-sharing (DBS) systems have been widely adopted in most cities since 2016. Globally, 37 percent of bike-sharing programs are in China (Metrobike 2017). Although there is a strong demand for shared e-bikes, due to safety and management concerns, many local policies have restricted the development of shared e-bikes.

Starting with the Chinese market, DBS start-ups put the idea of dockless bike-sharing into action, offering apps so riders can locate bicycles, and unlock and leave them wherever their rides end. Unlike public bike (docked) systems, the freedom of movement and the added convenience of dockless shared bikes have fulfilled a huge travel demand in Chinese cities for short-distance trips. In 2017, the number of dockless shared bikes in China was estimated at 23.0 million bikes at its peak, operating in over 200 Chinese cities. Although the fleet dropped to 19.5 million in late 2019, the DBS service has been operating in 360 Chinese cities since then. And China has still been recognized as the largest DBS market in the world (CAICT 2019; State Information Center 2018; Roland Berger 2018).

Benefits and issues

DBS has rapidly changed the transport ecosystem by furthering the development of the personal and convenient commute—typically catering to first/last-mile connectivity. However, an oversaturated market resulted in increases in fleet sizes, vandalism, clutter, and curbing of pedestrian space. Those challenges have led to debates when DBS was expanded into other cities. In addition, there is a lack of nationwide research and analysis on the impact of dockless shared bikes on travel behavior, public health, carbon emissions, road safety, and the urban environment. According to Shanghai municipal government, the city's reported monthly active bikes were only 0.56 million in December 2018, yet the DBS fleet was 1.15 million; this was a problem faced by other Chinese cities as well (Shanghai Municipal Transportation Commission 2019b).

As some DBS companies that jumped into the market with big fleet sizes in 2017 began to fold or go bankrupt by mid-2018, a vast number of unused or broken bikes were abandoned on streets or impounded in vacant areas in many cities, creating a waste of resources.

This market failure resulted from fierce market and capital competition at the early stage, as well as time lag in the standardization of regulations for this new transport service. Better parking and fleet management have been prioritized for city regulations, while dockless bike-sharing remains popular in China with a more reasonable and sustainable growth rate. Cities can take advantage of this opportunity by understanding the demand for car alternatives for short trips, and setting smart, goal-oriented regulations to encourage DBS services.

Research gap

The introduction of DBS services in Chinese cities has significantly increased cycling trips therein. Take Beijing as an example: from 2016 to 2018, daily cycling trips increased from 2.4 million to 4.5 million, and travel mode share increased from 10.3 to 11.5 percent in the city center, caused largely by the introduction of DBS systems (BTI 2019).

Based on international research findings, promoting cycling can benefit cities in many ways: for instance, by reducing emissions (Lindsay et al. 2011; Zhang and Batterman 2013; TRB 2002), through health gains (Rutter et al. 2013; Paluska and Schwenk 2000; Tainio et al. 2016), and by improving road safety (Wegman et al. 2012; Dill 2003; Fishman and Schepers 2018) regionally, as well as through the combined impact of benefits (Woodcock et al. 2014; Otero et al. 2018). However, active travel by cycling may increase risks of air pollution intake (Künzli et al. 2000) and road crashes (Teschke et al. 2012;

Wegman et al. 2012; Zegeer and Bushell 2012), leading to negative health impacts.

Many existing studies on bike-sharing (Sun 2018; Li et al. 2019; Jia et al. 2019; Si et al. 2019) and market reports (iiMedia Research 2019; CAICT 2019) have discussed the DBS systems in China, focusing mostly on the DBS business model, travel behavior characteristics, and limited impact analysis. However, a comprehensive nationwide impact analysis on DBS is needed to support the decision-making of relevant stakeholders, especially on travel behavior change, public health, emissions, road safety, and urban management.

1.2 Research Purpose

Considering the policy restrictions on shared e-bikes in Chinese cities and given that their impact on health and the environment are different from fully human-powered bikes, the "DBS" in this study only refers to fully human-powered bike-share systems. To fill in the gaps and understand how cities could be impacted by introducing the DBS service, this study answers three major questions.

- **Question 1:** Has DBS changed people's travel behavior? If so, how has it shifted people away from other transport modes?
- **Question 2:** What are the health, carbon, and safety impacts of the DBS?
- **Question 3:** What can cities do to improve DBS regulations?

Based on its findings, this study will link indicators with recommendations. These results will help target audiences achieve the following outcomes:

- **City decision-makers** will understand the quantitative net impact of the DBS, while also learning how to control risks and improve local regulations based on our results and recommendations.
- **The general public** can choose appropriate cycling durations per day to reach the maximum net health benefit based on our recommendations.
- **Researchers** will use the results to enrich similar studies across the globe, especially in terms of the impact assessment and regulations.

1.3 Structure of the Report

This report presents numerous discussions to answer the three questions about the impact of DBS in cities.

- Chapter 1 introduces the research background and objectives.
- Chapter 2 discusses the methodologies of the survey and impact assessments to address the main research questions.
- Chapter 3 shows the results of survey data analysis and elaborates on the impact of DBS on travel behavior change.
- Chapter 4 addresses the quantitative impact of DBS on health, carbon, and safety.
- Chapter 5 highlights successful regulation measures and cases of DBS management in China.
- Chapter 6 summarizes findings and limitations, and offers recommendations for future study.

CHAPTER 2

METHODOLOGIES AND DATA

To investigate the impact of DBS from different angles, multiple methodologies from different fields of study are required. The investigation includes but is not limited to survey inspection and analysis, health impact assessment methods, emission assessment methods, and policy review.

2.1 Research Methods Outline

To answer the questions in Chapter 1, this study combined survey inspection with other research literature and methodologies. As it is a recent mode of transport, DBS trips data have not been open to the public in many cities. To measure the impact of DBS, we chose to use survey inspection to collect the necessary data.

The research methodologies used to answer each research question are listed in Table 2-1, and detailed methodologies of survey inspection and impact assessment are discussed fully in Sections 2.2 and 2.3, respectively.

2.2 Survey Design and Sampling

Questionnaire design

To answer the research questions of this study, we designed the questionnaire to quantify key indicators (see Appendix I: Questionnaire). The following table lists the survey data to estimate impacts.

Cities selection

In China, over 360 cities have adopted dockless bike-sharing systems. We investigated the socioeconomic and urban transport information of 168 Chinese cities, and selected 12 cities: Shanghai, Beijing, Guangzhou, Shenzhen, Chengdu, Wuhan,

Table 2-1 | **The Research Methodology Outline**

Question	Impacts	Indicators/evidence obtained	Methods	Sources of input data
1	**Behavior change**	• DBS travel characteristics • DBS trips replacing other transport modes • Travel purpose	• Online DBS user survey with statistical analysis	• DBS survey by WRI China
2	**Physical activity benefit**	• Mortality avoided due to DBS cycling	• Comparative risk assessment • Dose-response functions (DRFs) from existing meta-analysis	• Research articles • DBS survey by WRI China • Transport data of cities
	Air pollution risk	• Mortality increased due to intake of ambient pollutants	• Comparative risk assessment • DRFs from existing studies	• Research articles • DBS survey by WRI China • Air quality data of cities • WHO database (e.g., GBD)
	Carbon reduction	• CO_2 reduced due to replacement of private motorized vehicles	• TESCA by WRI	• Research articles • DBS survey by WRI China • Transport data
	Crash risk	• Fatalities due to DBS cycling	• HEAT by WHO	• Research articles • Crash data • WHO database
3	**Urban environment**	• Fleet size control on oversupply • Parking management • Cycling facilities improvement	• Policy review	• DBS survey by WRI China • DBS-related policy and regulatory documents

Notes: 1. DBS user survey data to support impact estimates is expanded in Table 2-2.
2. All reviewed regulatory documents are summarized as a directory sheet in Appendix II.
3. TESCA = Transport Emissions and Social Cost Assessment; HEAT = Health Economic Assessment Tool for walking and for cycling (see details in Sections 2.2 and 2.3); WHO = World Health Organization; GBD = Global Burden of Disease.

Sources: Organized by authors

Hangzhou, Nanjing, Xi'an, Jinan, Xiamen, and Lanzhou. The selection is based on the key premise that the cities have a thriving bike-sharing culture, which requires cities to have more than one DBS operator and established public bike systems. The selection was also based on several other criteria including socioeconomic status, diversity of transport modes (including cities with and without metro systems), trips and air quality data availability, etc.

Data collection and sampling

The survey includes both dockless bike users and nonusers above 12 years of age, living in one of the 12 selected cities for more than half a year. The survey was conducted online due to considerations of time efficiency and budget limitations. We selected survey platform Wenjuanxing (WJX) as its sample pool has more than 2.6 million active members in China and can reach them through

Table 2-2 | **Survey Questions Designed to Estimate Different Impacts**

Question	Indicators	Survey questions asked to estimate impacts
1	**Behavior change**	• DBS travel characteristics: distance, frequency, travel time • DBS trips replacing other transport modes • DBS used to connect with other transport modes • Travel purpose • Reasons for liking or disliking DBS
2	**Physical activity benefit**	• DBS travel characteristics: distance, frequency, travel time • People's attitudes toward the health impacts of using DBS
	Air pollution risk	• People's attitudes toward the air pollution risks of using DBS
	Carbon reduction	• DBS travel characteristics: distance, frequency, travel time • DBS trips replacing other transport modes • Mileage of private vehicle use: cars, taxis, ride-hailing, motorcycles
	Crash risk	• Perceived road safety risks of using DBS
3	**Urban environment**	• People's attitudes toward the DBS obstruction issue

Sources: Organized by authors.

Table 2-3 | **A Brief Portfolio of Selected Study Cities**

City Name	Population (residents)	Per capita GDP (USD)	Metro	Thriving bike-sharing culture	$PM_{2.5}$ concentration ($\mu g/m^3$)	DBS fleet size (thousands)
Shanghai	24,183,300	17,801	√	√	36.0	500
Beijing	21,707,000	18,427	√	√	51.0	900
Chengdu	15,908,000	12,473	√	√	51.0	700
Guangzhou	14,498,400	21,188	√	√	35.0	400
Shenzhen	12,528,300	25,586	√	√	26.0	480
Wuhan	10,914,000	17,553	√	√	49.0	750
Hangzhou	9,468,000	18,945	√	√	40.0	390
Xi'an	9,450,000	10,893	√	√	61.0	450
Nanjing	8,335,000	20,079	√	√	43.0	317
Jinan	7,060,000	14,573		√	52.0	180
Xiamen	4,000,000	15,357	√	√	25.0	150
Lanzhou	3,729,600	8,673		√	47.0	290

Notes: 1. The $PM_{2.5}$ concentration data (average value in 2018) are collected from the 2018 *Ecology and Environment Annual Report* of the local Municipal Bureaus of Ecology and Environment.
2. Demographic data are collected from the local Statistics Bureaus and the National Bureau of Statistics (NBS) Survey Office in 2018.
3. The DBS fleet size data are the most recently updated available data, collected from January 2018 to July 2019.

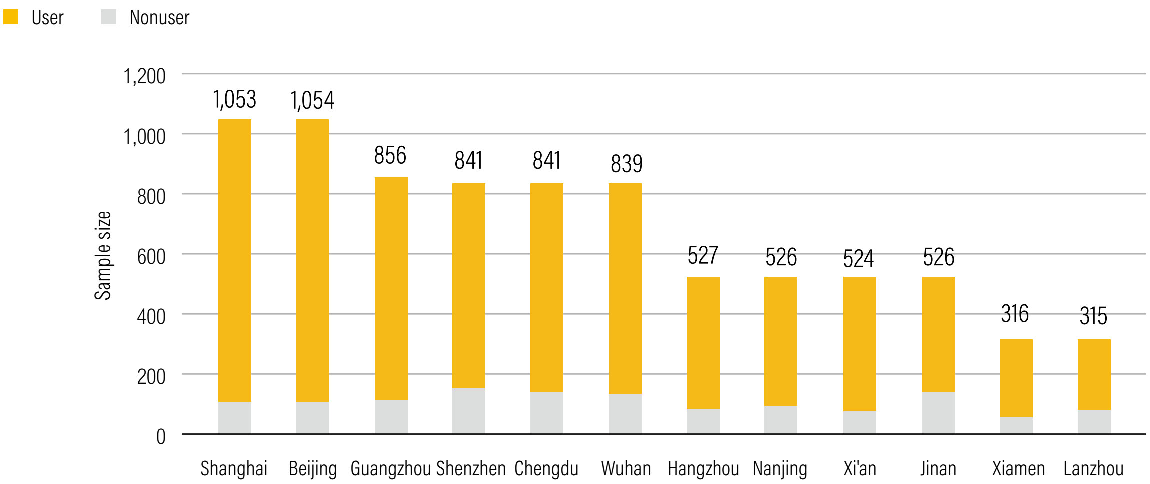
Sources: Shanghai Statistics Bureau and NBS Survey Office 2018; Shanghai Municipal Bureau of Ecology and Environment 2019; Beijing Statistics Bureau and NBS Survey Office in Beijing 2018; Chengdu Statistics Bureau and NBS Survey Office in Chengdu 2018; Guangzhou Statistics Bureau and NBS Survey Office in Guangzhou 2018; Shenzhen Statistics Bureau and NBS Survey Office in Shenzhen 2018; Wuhan Statistics Bureau and NBS Survey Office in Wuhan 2018; Hangzhou Statistics Bureau and NBS Survey Office in Hangzhou 2018; Xi'an Statistics Bureau and NBS Survey Office in Xi'an 2018; Nanjing Statistics Bureau and NBS Survey Office in Nanjing 2018; Jinan Statistics Bureau and NBS Survey Office in Jinan 2018; Xiamen Statistics Bureau and NBS Survey Office in Xiamen 2018; Lanzhou Statistics Bureau and NBS Survey Office in Lanzhou 2018; Beijing Municipal Bureau of Ecology and Environment 2019; Nanjing Municipal Bureau of Ecology and Environment 2019; Xiamen Municipal Bureau of Ecology and Environment 2019; Shenzhen Municipal Bureau of Ecology and Environment 2019; Hangzhou Municipal Bureau of Ecology and Environment 2019; Chengdu Municipal Bureau of Ecology and Environment 2019; Wuhan Municipal Bureau of Ecology and Environment 2019; Guangzhou Municipal Bureau of Ecology and Environment 2019; Bicycle Fan 2019; Yu 2019; Jiang 2018; Wu 2019; Wuhan Broadcasting Station 2018; Zhejiang News Broadcasting 2019; Qianzhan Industry Research Institute 2019; Xiao and Zhang 2018; *Xinmin Evening News* 2019; Xi Wang 2019; Hbspcar 2018; J. Xu 2018; Ministry of Housing and Urban-Rural Development of China 2017; P. Yin and Zhou 2016; *CCTV News* 2019; *Xinhua News* 2019; Xia 2019.

multiple channels, including e-mails, mobile phone apps, WeChat messages, etc. The online survey was conducted from September 17 to October 8, 2018, which is the height of the bike season due to comfortable temperatures and are back-to-school months for students.

In practice, we divided the cities into four sampling groups according to population size. As cities with large populations, Beijing and Shanghai aimed for 1,000 valid responses; Guangzhou, Shenzhen, Chengdu, and Wuhan aimed for 800; Hangzhou, Nanjing, Xi'an, and Jinan aimed for 500; and Xiamen and Lanzhou aimed for 300. A total number of 8,218 valid responses were received, including 84 percent DBS users and 16 percent nonusers (Figure 2-1). Sampled DBS user data are used to estimate the impacts of using DBS systems at the national level. The DBS user impact analysis is expanded in Chapter 3.

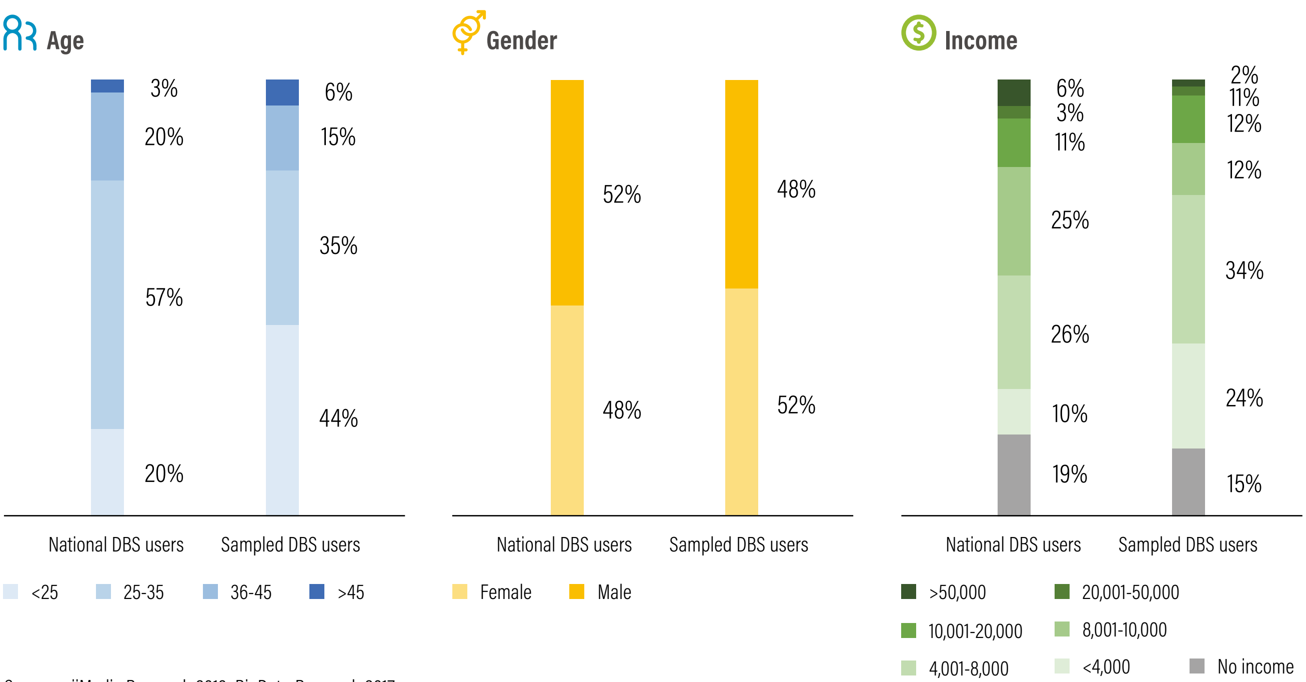
In addition to DBS users, a certain amount of nonuser samples were also collected and combined to show people's attitudes toward obstruction, road safety, health, and cycling in polluted air; discussion on this is expanded in Chapter 4.

Figure 2-1 | **Valid Sample Collected in the Twelve Cities**



Notes: Invalid respondents were excluded if Internet Protocol (IP) address does not match, the total survey response time was less than 100 seconds, and the user was younger than 12 years old[5].
Sources: Survey results.

Figure 2-2 | **Comparing the Demographic Characteristics of National DBS Users and Sampled DBS Users**



Sources: iiMedia Research 2019; BigData-Research 2017.

For sampled DBS users, compared with the reported national DBS user demographic structure (iiMedia Research 2019; BigData-Research 2017), the collected valid DBS user responses (n = 6,902) are characterized as gender-balanced, but with a higher proportion of young and middle- and low-income groups, as there are more young and a larger number of heavy users in the sample pool (see Figure 2-2). In such a case, further surveys should be conducted to present a more accurate representation of the population.

2.3 Methods of Impact Assessment

We adopted different methods to quantify the four indicators in Table 2-1 to address Question 2; that is, physical activity benefit, air pollution risk, carbon reduction, and crash risk of DBS users. We combined the first two indicators to assess the net health benefit (or cost) of DBS cycling activity and air pollutant exposure. Figure 2-3 below shows a brief methodology framework to assess the health, carbon, and safety impacts of DBS cycling in this study. Note that both assessment results of the "health impact" and "road safety impact" in this study are compared to the implicit case of "no cycling"[6]; while "carbon impact" is compared to the case before motorized trips were replaced by DBS (see each of the methodologies and assumptions in the following section).

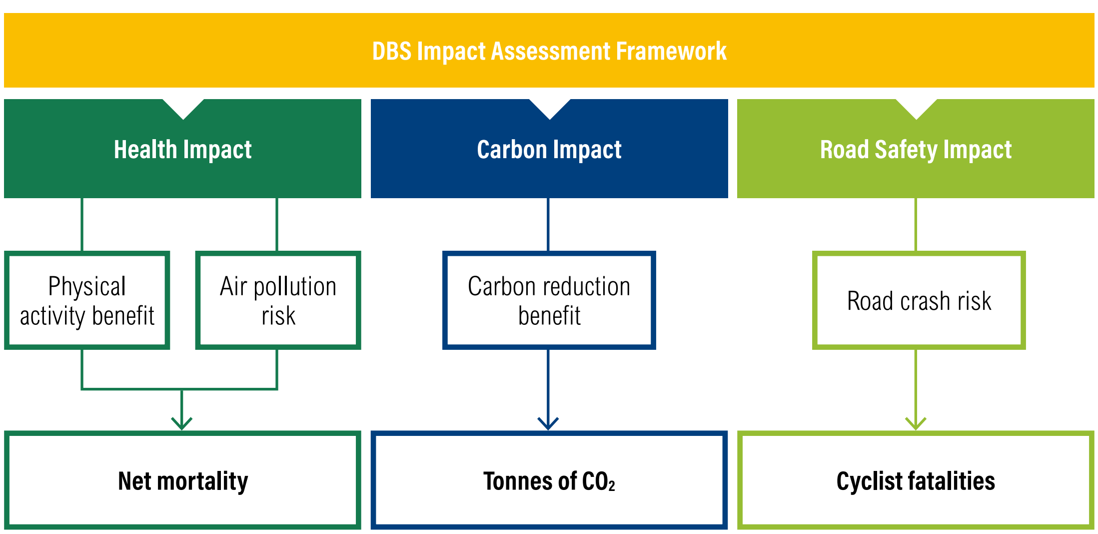
For the impact assessment above, we referred mainly to methods from the World Health Organization (WHO's) guideline "Health Economic Assessment Tool for Walking and for Cycling—Methods and User Guide on Physical Activity, Air Pollution, Injuries and Carbon Impact Assessment" (HEAT) (Kahlmeier et al. 2017), the World Resources Institute (WRI's) "Transport Emissions and Social Cost Assessment: Methodology Guide" (TESCA 1.0) (Song 2017), as well as to some reviewed research (Kelly et al. 2014; Woodcock et al. 2011, 2014; Tainio et al. 2016). A brief summary of the methodologies and calculations are presented in the text that follows.

Health impact due to cycling and air pollution

In the health impact assessment, we used the relative risk (RR) to describe the potential health benefit or risk due to a certain level of physical activity (cycling) and air pollution exposure. Relative risk,[7] or risk ratio, is the ratio of the probability of an outcome in an exposed group to the probability of an outcome in an unexposed group (Porta 2014). It measures the association between the exposure and the outcome (Sistrom and Garvan 2004).

We used all-cause mortality (ACM) as the health outcome (Tainio et al. 2016), since the evidence shows its association with both long-term physical activity and long-term $PM_{2.5}$ exposure (Kelly et al. 2014; Héroux et al. 2015).

Figure 2-3 | Conceptual Framework of the Impact Assessment Method of the DBS System



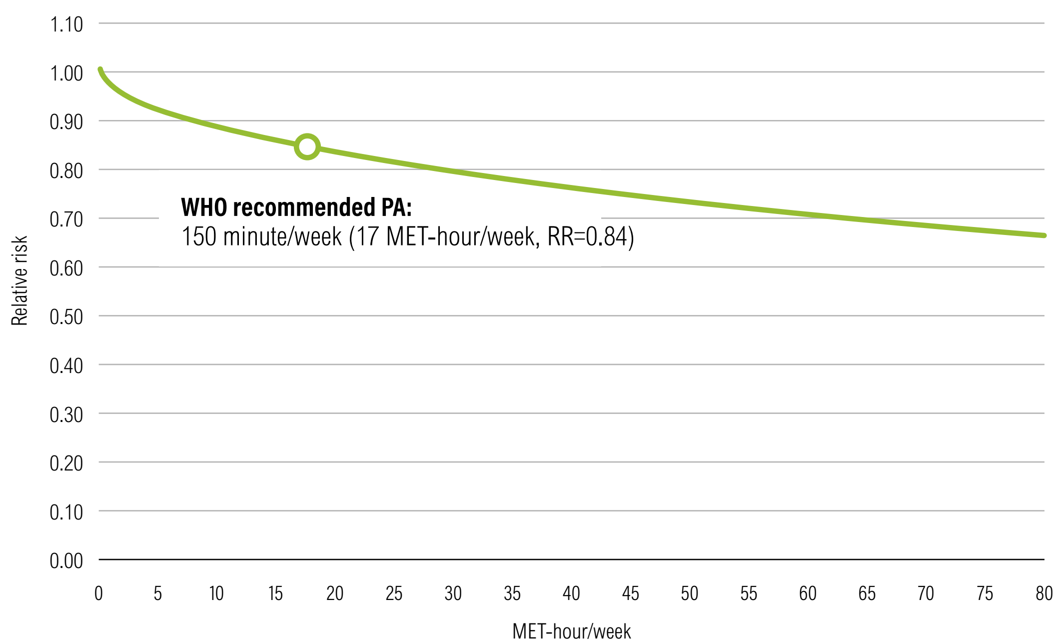
Sources: Organized by authors

Physical activity benefit

We converted the cycling activity (frequency, duration, and distance) into the metabolic equivalent of task (MET)[8] hour per week (MET-hour/week), since this standardized expression integrates both the intensity and the duration of the reported physical activities (PAs). We assumed the average intensity for cycling as 6.8 METs, which is widely used in cycling- and walking-specific research (Tainio et al. 2016; Kahlmeier et al. 2017; Kelly et al. 2014). The MET intensity level was from the 2011 Compendium of Physical Activities," Code 01011: "Bicycling, to/from work, self-selected pace" (Ainsworth et al. 2011).

The relative risk (RR) of ACM lessens as PA increases. The risk reduction in ACM from cycling was then estimated by applying the cycling activity (in MET-hour/week) into the dose-response functions (DRFs) used in international studies (Kelly et al. 2014; Tainio et al. 2016). The DRF depicts the analyses of mortality risk as a function of physical activity (in MET-hours/week). Based on the study by Tainio et al. (2016) and a comparision between linear and nonlinear DRFs (see Box 2-1), we adopted the "0.5 power transformation" as a compromise between linear and extremely nonlinear DRFs (Figure 2-4). Data of the cycling activity level can be obtained from the DBS survey.

Figure 2-4 | **Dose-response Function of the Health Risk and Physical Activity of Cycling**



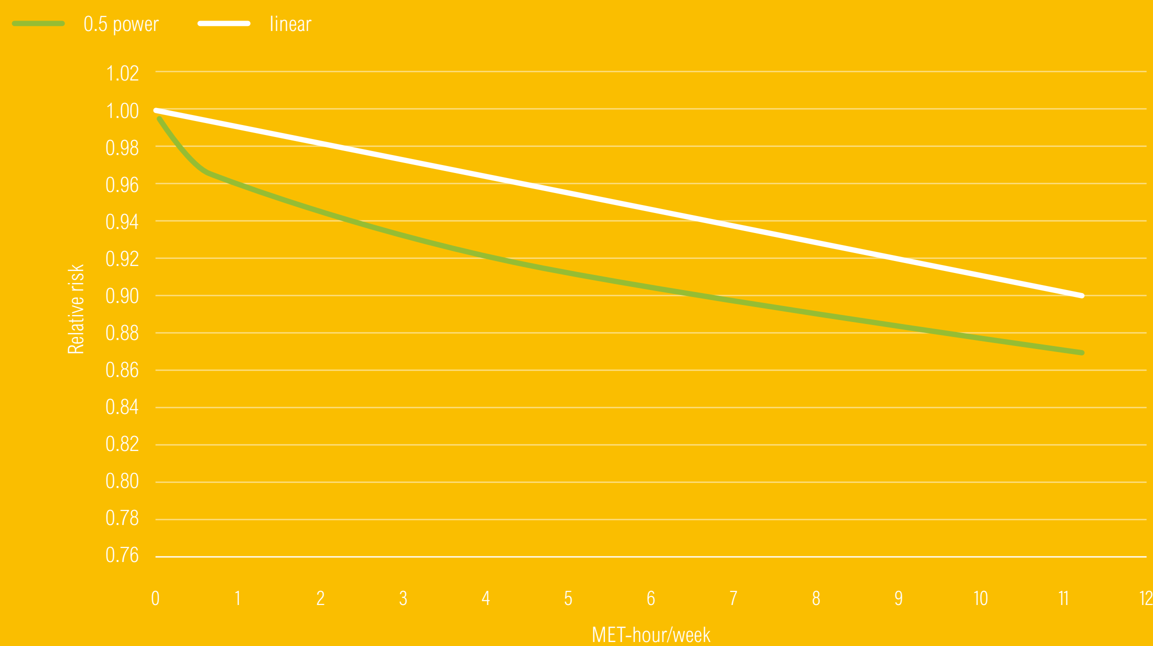
Note: In this study, we assume the maximum cycling duration would be 100 minutes/day, equivalent to about 80 MET-hours/week (cycling at 6.8 METs).

Source: Data adapted from Tainio et al. 2016; Kahlmeier et al. 2017; Kelly et al. 2014; WHO 2020. MET intensity for cycling = 6.80. RR (cycling at 11.25 MET-hours/week) = 0.87 (95% CI 0.83–0.91) for 0.5 power transformation DRF; RR (cycling at 11.25 MET-hours/week) = 0.90 (95% CI 0.87–0.94) for linear DRF (Kelly et al. 2014).

Box 2-1 | Comparison between Linear Dose-Response Function and Nonlinear Dose-Response Function

It is important to note here that the choice of the shape of DRF will influence the results. WHO's HEAT chose the linear instead of the nonlinear DRF to avoid additional data requirements on baseline activity levels, though literature suggests that the DRF between physical activity and relative risk of mortality is most likely nonlinear (Kahlmeier et al. 2017). Based on the results of Kelly et al. (2014), we found that within certain exposure levels (e.g., cycling for 12 MET-hours/week or 15 minutes/day), 0.5 power DRF overestimates the health effect of cycling while linear DRF underestimates it (see Figure B2-1). The shapes of both DRFs are similar within such level, though linear DRF seems to have a larger variation in the results than 0.5 power DRF.

Figure B2-1 | Linear vs. 0.5 Power DRF within 12 MET-hours/week



Air pollution risk

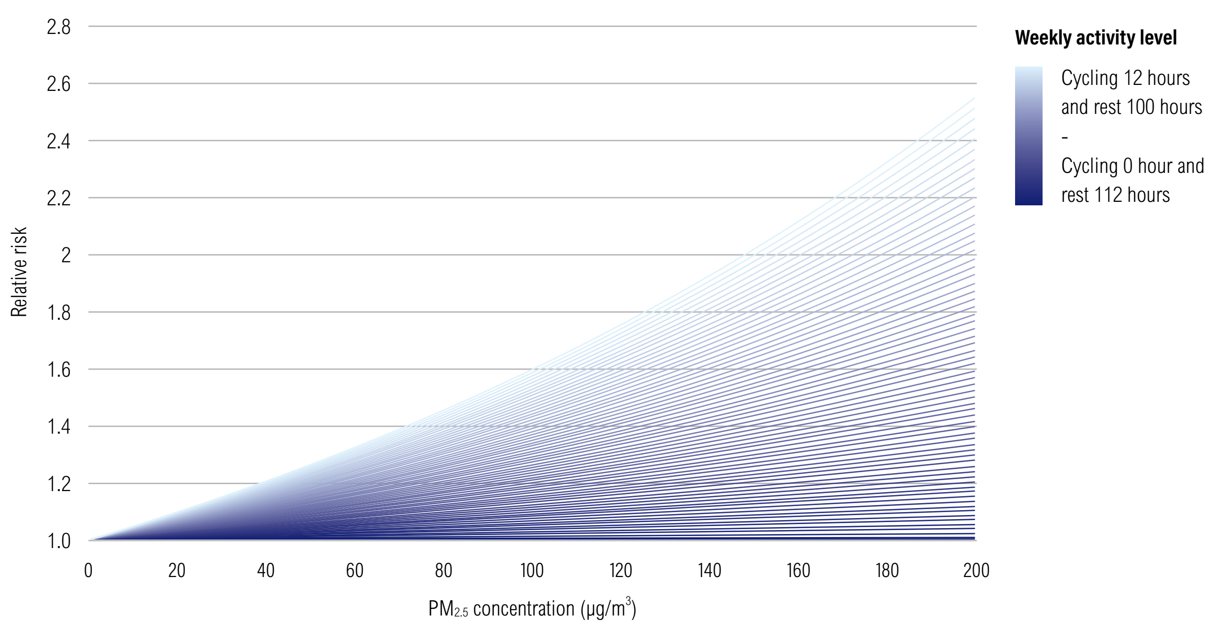
We selected **$PM_{2.5}$** as the key indicator of air pollution since it caused a large burden on public health globally (Tainio et al. 2016; GBD 2017 Risk Factor Collaborators 2018). We adopted the prevailing method from several international studies (Doorley et al. 2015; Mueller et al. 2015; Tainio et al. 2016) to quantify the health impact of active travel. This study considers that inhalation of $PM_{2.5}$ rises as people increase their physical activity and/or in a more ventilated environment. Based on the method used in the study by Tainio et al. (2016), the health risk of $PM_{2.5}$ was estimated by converting background $PM_{2.5}$ concentrations to travel mode–specific exposure concentrations (e.g., cycling), and by taking into account the ventilation rate while being active. We also adopted all basic assumptions in the studies by Tainio et al. (2016) and Kahlmeier et al. (2017). A summary of the formulas and the assumptions is presented in Table 2-4 below.[9]

Table 2-4 | **Dose-Response Function of the Health Risk of $PM_{2.5}$ Due to Cycling**

Formulas	Assumptions/Inputs	Sources
Mode-specific $PM_{2.5}$ concentration ($\mu g/m^3$) *=background $PM_{2.5}$ concentration × conversion rate for cycling*	• Conversion rate for cycling: 2.0 • Background $PM_{2.5}$: 5μg/m^3 to 200μg/m^3 with 5μg/m^3 intervals.	WHO 2014a; Kahlmeier et al. 2017; Tainio et al. 2016
Inhaled dose per week (μg/week) *=Σ_i($PM_{2.5}$ concentration × duration × ventilation rate)*	• i: sleep, rest, cycling • Duration (hour/week): sleep = 56; rest = 112 (can include cycling) • Ventilation rate (m^3/h): sleep = 0.27; rest = 0.609; cycling = 2.55	WHO 2014a; Kahlmeier et al. 2017; Tainio et al. 2016
Increase in $PM_{2.5}$ concentration due to cycling ($\mu g/m^3$) $= \left(\frac{\text{total inhaled dose}}{\text{reference dose}} - 1\right) \times \text{background } PM_{2.5} \text{ concentration}$	• Or called the "equivalent change" • Reference dose: sleep dose + rest dose (without cycling)	WHO 2014a; Tainio et al. 2016
Relative risk of $PM_{2.5}$ due to cycling $=Exp[(Ln(RR \text{ per } 10\mu g/m^3 \text{ change}) \times \left(\frac{\text{increase in } PM_{2.5} \text{ concentration due to cycling}}{10}\right)]$	• RR per 10μg/m^3 change: DRF for background $PM_{2.5}$, in which we assume RR of 1.07 (CI 95% 1.04-1.09) per 10μg/m^3 change in exposure. And we assume the DRF is linear. • Assume DRF for background $PM_{2.5}$ is linear from zero to maximum inhaled dose.	WHO 2014b; Tainio et al. 2016; Kahlmeier et al. 2017

Sources: WHO 2014a; Kahlmeier et al. 2017; Tainio et al. 2016; WHO 2014b.

Figure 2-5 | **Dose-Response Curves of Health Risk and $PM_{2.5}$ Exposure at Different Cycling Levels**



Note: Each line represents the combination of different types of physical activity with different durations, including sleep, rest, and cycling. In Tainio et al.'s study (2016), the duration of sleep was fixed as 8 hours in all scenarios, and the rest time was 16 hours minus the time for active travel (cycling). Durations of cycling are different, which makes the lines different in the above figure.
Source: Tainio et al. 2016.

By applying the background $PM_{2.5}$ concentrations and the cycling activity data (i.e., duration) into the DRFs in Figure 2-5, the RRs (due to different cycling durations) of $PM_{2.5}$ exposure can be estimated. The data of cycling duration can be obtained from the DBS survey, while the city-level background $PM_{2.5}$ concentration data are obtained from online databases from WHO, Ministry of Ecology and Environment of China (MEE), and other sources (WHO 2019a, 2019b; Xiaolei Wang 2019).

Estimation of health impact

We used the "mortality changed" to represent the health impact caused by the DBS system. We adopted the comparative risk assessment (CRA) method to estimate changes in the burden of disease due to the **combined effect of physical activity and air pollution exposure.** The methods of CRA have been widely used and extensively described in global literature (Ezzati et al. 2004; Hoorn et al. 2004; Woodcock et al. 2009). Therefore, we did not describe the detailed methods in this report. Based on the method, the burden of disease—measured by the number of mortalities—is expressed in the following equation (1) (Huang et al. 2018; WHO 2014a):

$$\Delta Mortality_a = PAF_a \times MR_{o,a} \times Pop_a = \left(\frac{RR_a - 1}{RR_a}\right) \times MR_{o,a} \times Pop_a \quad (1)$$

where, $\Delta Mortality_a$ is the death change attributable to the combined effect of cycling and $PM_{2.5}$ exposure; PAF_a is the population-attributable fraction (or attributable fraction),[10] which can be calculated by RR_a; RR_a is the relative risk of the combined effect of cycling and $PM_{2.5}$ exposure. According to Tainio et al.'s study (2016), it is obtained from the RR of cycling multiplied by the RR of $PM_{2.5}$ exposure; $MR_{o,a}$ is the baseline mortality rate of a specific health outcome (in this study the ACM); Pop_a is the size of the exposed population; a represents the specific age (which is not broken into subgroups in this study).

The data of $MR_{o,a}$ could be found from the United Nations' World Population Prospects 2019 (United Nations 2019a, 2019b),[11] WHO's Global Health Observatory (GHO) data repository (WHO 2019a),[12] and the "Global Burden of Disease Study 2017 Data Sources" from the Institute for Health Metrics and Evaluation (IHME 2019)[13] and the GBD Compare (IHME 2015).[14] In this study, we used the $MR_{o,a}$ value for age 15–64 years in China, which is consistent with the age range in the sample survey. The value of $MR_{o,a}$ is 2.528 deaths per 1,000 population or 0.2528 percent, calculated based on the data from the United Nations (United Nations 2019a, 2019b). We also obtained the data of Pop_a from the DBS user experience survey, in which it is the number of users in samples. To estimate the total mortality avoided among the nation's DBS users, we assumed Pop_a as roughly 235 million DBS users in China in 2018 (Wong and Liu 2019).

Emission reductions

In this study, we only calculated the reduction in emissions due to the trips shift from private motorized modes (i.e., private car, taxi, ride-hailing, and motorcycle) to DBS cycling. Although three types of greenhouse gases (GHGs) (CO_2, CH_4, N_2O) and six types of air pollutants (NO_x, SO_x, PM_{10}, $PM_{2.5}$, CO, HC) can be estimated by the traditional equation (2), we only estimated the reduction in CO_2 emissions. Evidence from our study shows that the reduction in other air pollutants is far from significant due to the short travel distance replaced by DBS, so we decided not to present those results in this report.

$$Emissions = \sum_{i,j} (D_{i,j} \times FE_{i,j} \times EF_{i,j}) \ or \ \sum_{i,j} (D_{i,j} \times EF_{i,j}) \quad (2)$$

where, i,j represents the type of transport mode and fuel, respectively; $D_{i,j}$ are the private motorized travel distances replaced by DBS; $FE_{i,j}$ is the fuel efficiency of private motorized transport (in liter/kilometer [l/km] or tonne/kilometer [tonne/km], depending on different fuel types); $EF_{i,j}$ is the emission factor for different GHGs or air pollutants (in grams/liter [g/l] or grams/kilometer [g/km], depending on different emission types).

Data of $D_{i,j}$ can be obtained from the DBS user experience survey. Data of $EF_{i,j}$ and $FE_{i,j}$ can be obtained from various official sources such as the Ministry of Ecology and Environment of China (MEE 2014), Ministry of Transport, local municipal government departments and research institutes, international organizations such as the Intergovernmental Panel on Climate Change (IPCC) and WRI, and some research articles and tools (Song 2017). In some cases, $D_{i,j}$ could be indirectly calculated from mode split data. Mode split data can be obtained from various sources such as the city's transport authority, household travel survey, and existing literature.

DBS traffic fatalities

Studies comparing the risk of injury to cyclists of all kinds of shared bikes have shown mixed results. The proportion of head injuries in some American cities has increased after the implementation of shared bike facilities (Graves et al. 2014), while bike safety data from other global cities reported the opposite trend (Fishman and Schepers 2016; Salomon et al. 2014). In this study, we assumed that the exposed risks (per mile) for DBS users and cyclists of all kinds are the same. Therefore, DBS traffic fatalities can be calculated based on the following equation (3):

$$\textit{DBS fatalities} = \textit{bike fatalities} \times \left(\frac{\textit{DBS kilometer traveled}}{\textit{bike kilometer traveled}}\right) \tag{3}$$

where, DBS fatalities and *bike fatalities* are annual fatalities of DBS users and all cyclists; *DBS kilometer traveled* and *bike kilometer traveled* are the total distance traveled in one day by DBS users and all cyclists, respectively. These three factors can be estimated as in the following equations (4)–(8):

$$\textit{bike fatalities} = \textit{road traffic fatalities} \times \textit{bike death share} \tag{4}$$

$$\textit{DBS kilometer traveled} = \textit{ave.DBS trip distance} \times \textit{DBS trips} \tag{5}$$

$$\textit{DBS trips} = \textit{DBS share} \times \textit{bike trips} \tag{6}$$

$$\textit{bike trips} = \textit{urban pop} \times \textit{trip rate} \times \textit{bike mode share} \tag{7}$$

$$\textit{bike kilometer traveled} = \textit{bike trips} \times \textit{ave.bike trip distance} \tag{8}$$

where,
road traffic fatalities are the latest annual road fatalities in China reported by WHO (2018a). *Bike death share* is the cyclist fatality share among all road injuries, obtained from the latest statistics (WHO 2016).

DBS kilometer traveled is estimated by two factors. *Average DBS trip distance* is obtained from the survey result. And *DBS trips* are calculated by multiplying *bike trips* by *DBS share*, which is estimated based on empirical studies (Fan et al. 2019), following the equation (6) of *DBS trips = DBS share × bike trips*. Due to the scarcity of national-level travel data, bike trips estimation is based on the HEAT model by multiplying the total urban population (urban population), the number of all-mode trips per person per day (*trip rate*) and average bike mode share in Chinese cities (*bike mode share*), following the equation (7) of *bike trips=urban pop×trip rate×bike mode share.*

Then *bike kilometer traveled* can be calculated by *bike trips,* multiplying the average distance per bike trip (average bike trip distance) in equation (8).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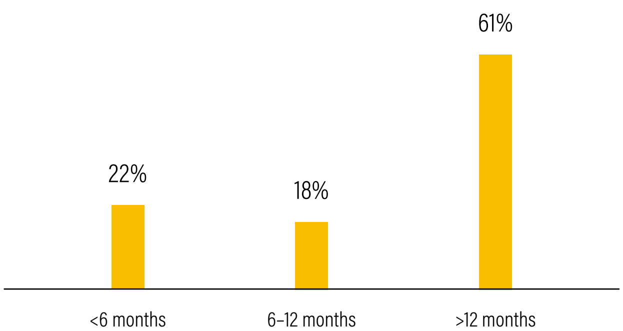
CHAPTER 3

IMPACTS ON TRAVEL BEHAVIOR

For short and medium trips, people tend to use DBS over walking and buses, to save time. The survey results indicate that the DBS system is more than a replacement for walking and buses on short-distance trips; DBS enhances connectivity to public transit systems and has great potential for replacing motorized trips in cities.

This chapter shows the preliminary analysis based on collected DBS user responses (n = 6,902). It answers the first research question on how DBS changes people's travel behavior. The results show how individuals use and engage with the DBS system, and how it can affect travel behavior by encouraging sustainable transport. Moreover, the analysis focuses on how DBS explicitly interrupted the existing urban mobility system, especially by connecting public transport and replacing private motorized trips.

Figure 3-1 | **How Long Have People Been Using Dockless Shared Bikes?**



Note: n = 6,902.
Source: Survey results.

This chapter does not discuss survey results for each separate city. Even though the cities included in this study have large geographical and socioeconomic differences (see Table 2-3), preliminary results show that DBS has a homogenous impact on travel behavior among all 12 cities.

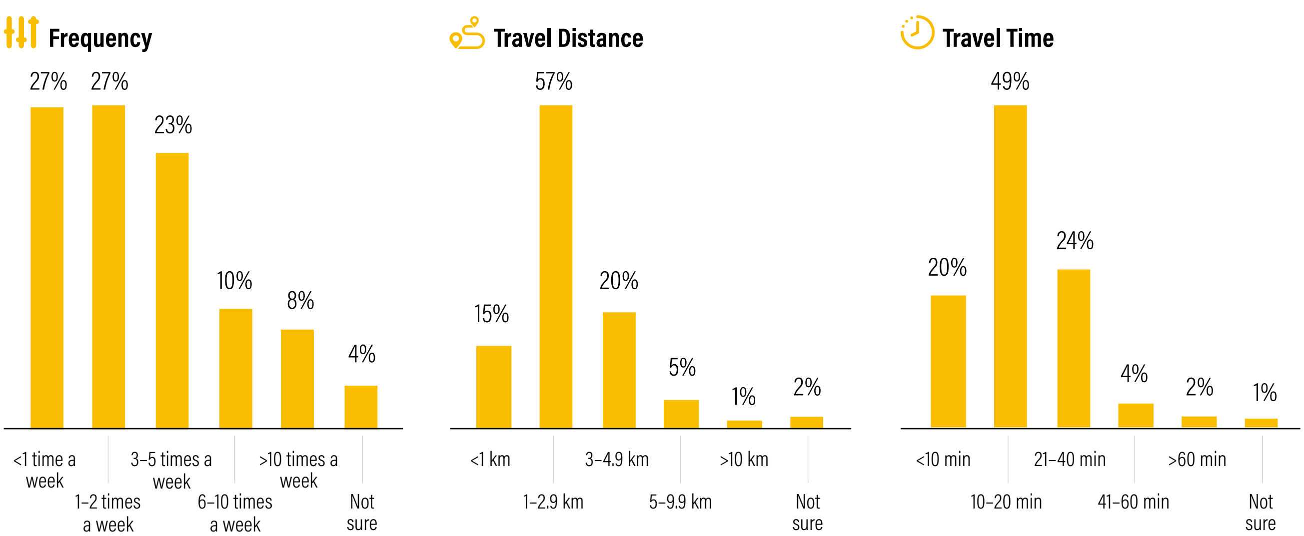
Until the end of 2018, among the survey's DBS users, more than 60 percent had used dockless shared bikes for over one year since DBS entered the market in late 2016, and the DBS service had still attracted new users (shown in Figure 3-1). The results showed a high penetration of DBS in the cities in this study.

3.1 Frequency, Distance, and Duration

Strong patterns emerged among DBS users (n = 6,902) of dockless shared bikes as a means of travel, as summarized in Figure 3-2.

- The majority (77.8 percent) of DBS users ride less than five times a week, whereas 18.0 percent of users ride more than six times a week.
- 92 percent of DBS users travel less than 5 kilometers, and among them, 57 percent ride for

Figure 3-2 | **DBS User Travel Frequency, Distance, and Travel Time in the Past Six Months**



Notes: n = 6,902 The original survey questions:
1. How often have you used the dockless shared bike in the past six months?
2. What distance do you typically travel per bike trip?
3. Minutes per bike trip

Source: Survey results.

1–3 kilometers. Alternatively, 72 percent of trips are less than 3 kilometers in distance covered.

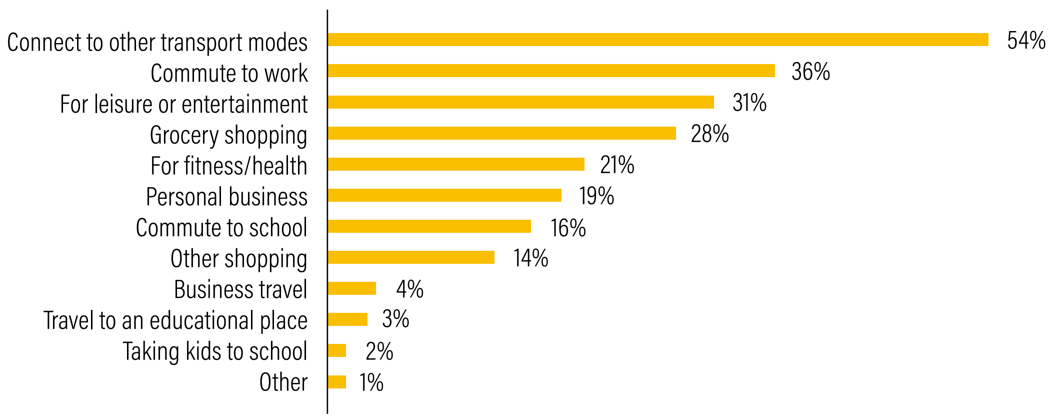
- Among all DBS users, up to 93.2 percent traveled less than 40 minutes, and among these, more than half of users' travel time was 10 to 20 minutes.

3.2 Travel Purpose

Survey results show that DBS systems have provided a solution for short-distance travel between transit stations and destinations/origins and have promoted an integrated urban transport system.

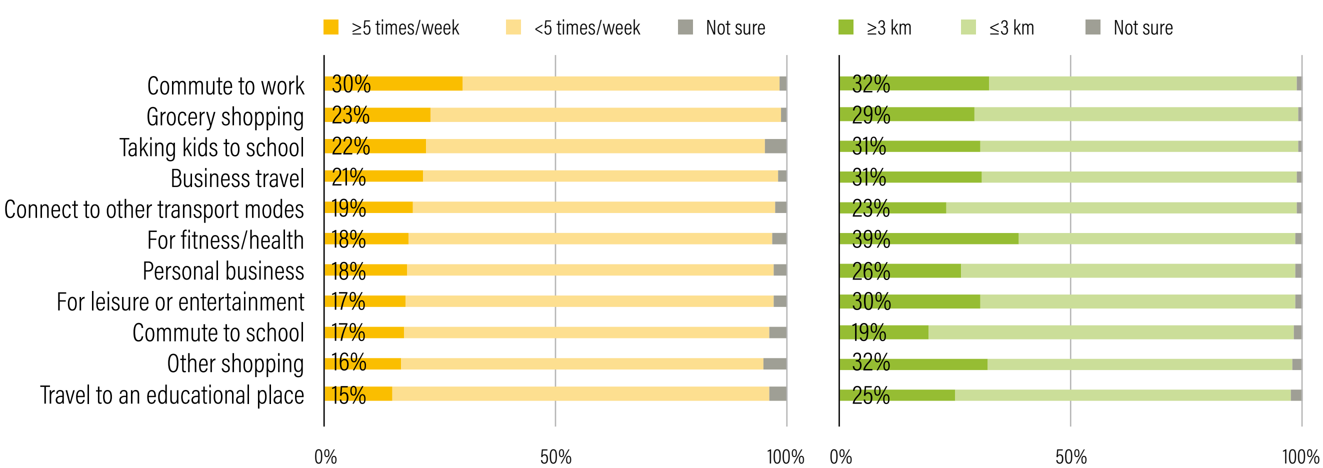
- 54 percent of users selected DBS for its convenient connections to other transport modes (Figure 3-3). For this travel purpose, 81 percent of DBS users' travel distance is less than 5 kilometers (Figure 3-4).
- 36 percent used dockless bikes for the daily work commute (Figure 3-3). DBS systems are widely used in commuting as an emerging mode, to complete either the partial or entire trip. Additionally, for this travel purpose, 30 percent of DBS users biked more than five times a week, which is a much higher frequency compared with other purposes. Also, DBS is used to travel longer work commuting distances, as 32.2 percent of users cycle more than 3 kilometers per trip (Figure 3-4).

Figure 3-3 | **What Is Your Travel Purpose (or Destination) by Dockless Shared Bikes? [Select up to 3]**



Notes: n = 6,902
Source: Survey results.

Figure 3-4 | **DBS Travel Frequency (left) and Distance (right) Distribution for Each Travel Purpose**



Notes: n = 6,902
Source: Survey results.

3.3 Last-Mile Connection

For the last-mile trips, over 80 percent used DBS bikes to connect to public transit, which means DBS has been a popular complement to the urban public transport system (Figure 3-5).

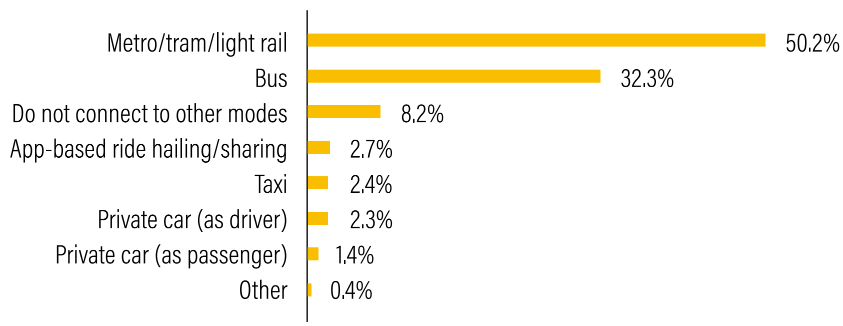
- 50.2 percent of DBS users traveled to connect to metro or other railway system.
- 32.3 percent of DBS users traveled to connect with regular buses.
- 8.2 percent used DBS bikes to complete their entire trips, without combining with other modes of travel.

3.4 Travel Modes Replaced by DBS

To investigate how the emergence of DBS bikes affects the ridership of other transport modes, we asked people how they made their riding trips before the emergence of DBS. The results show that DBS served mainly as a substitution for walking and regular buses, mostly for travel distances within 5 kilometers (Figure 3-6).

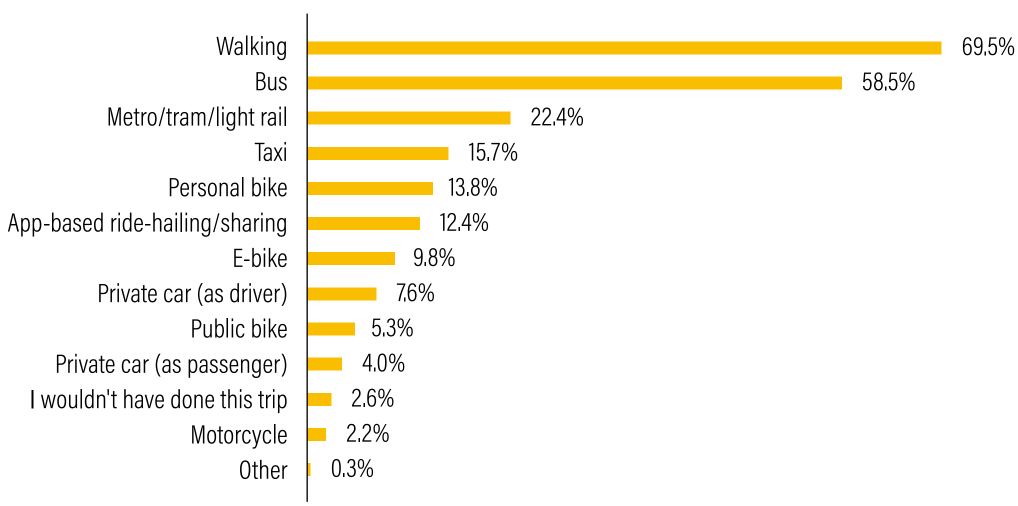
- 70 percent of DBS users would have walked as an alternative mode in the absence of DBS.
- Nearly 59 percent of DBS users would have taken the bus as an alternate mode in the absence of DBS.

Figure 3-5 | **What Other Modes (Excluding Walking) Do You Combine with the DBS Trip? [Select up to 3]**



Notes: n = 6,902
Source: Survey results.

Figure 3-6 | **Thinking about the Trip You Make Most Frequently with the Dockless Bike-Sharing System—How Did You Make This Trip before Joining the System? [Select up to 3]**



Notes: n = 6,902
Source: Survey results.

- 16 percent and 12 percent shifted from taxis and ride-hailing services, respectively. Also, 8 percent and 4 percent shifted from private cars as drivers and passengers, respectively.
- DBS generated 3 percent of new trips, changing people's previous travel routine.

3.5 Why Travel by DBS

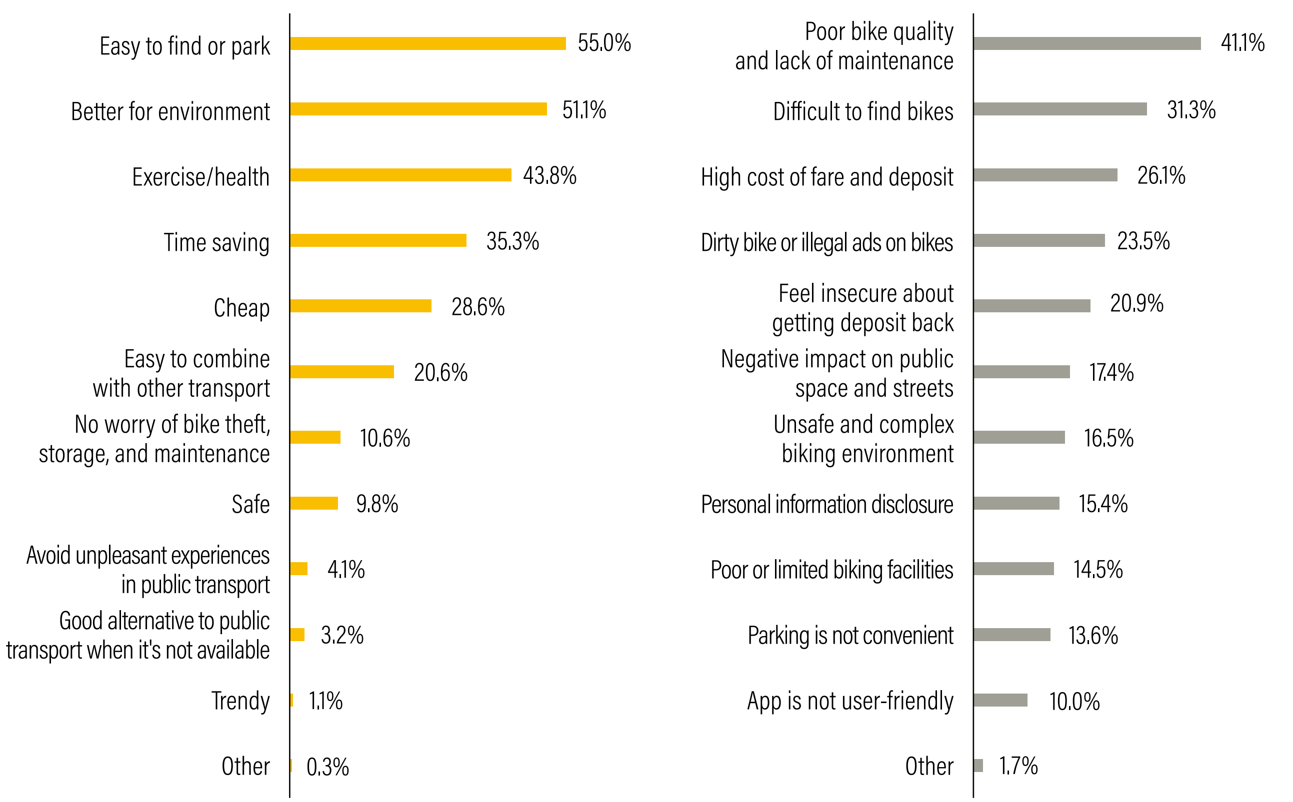
From the results, we found that people like and dislike dockless shared bikes for similar reasons among cities (Figure 3-7).

- The top three positive reasons are (1) easy to find/park the bikes (55 percent), (2) better for the environment (51 percent), and (3) good for health (44 percent).
- As for the negative aspects of the shared bike, the top three reasons are (1) poor quality and maintenance of bikes (41.0 percent), (2) difficulty finding bikes (31.3 percent), and (3) high cost of fares and deposits (26.0 percent).

It's worth noting that people found that DBS bikes are both easy and difficult to find. This conflict may be the result of the uneven distribution and poor management of fleets. The accessibility of bikes varies across locations. Availability and flexibility are the advantages of dockless bikes, which could be maximized by a more responsive distribution of the fleet.

Overall, the top three reasons people dislike DBS are issues that the cities have targeted to resolve. Chapter 5 investigates regulations and policies of the 12 cities, in aspects of fleet control, parking, and infrastructure improvement. Although deposit management does not fit the research scope of this study, the new

Figure 3-7 | **The Reasons People Like and Dislike DBS Bikes**



Notes: n = 6,902 Original survey questions:
1. What are the reasons you like using the dockless shared bike? [Select up to 3]
2. What are the reasons you disike using the dockless shared bike? [Select up to 3]

national mobility services deposit management regulation is introduced briefly in Box 3-1.

Box 3-1 | User Deposit Management: Refund Policy

To address the high deposit and avoid situations where operators would not be able to refund deposits due to bankruptcy, in 2019, the Ministry of Transport, the People's Bank of China, and the National Development and Reform Commission (NDRC) introduced the Measures of New Mobility Services Deposit Management (MoT et. al. 2019) to further protect and manage user deposits.

The Measures ask that new mobility services operators, such as bike-sharing, ride-hailing, and car-sharing companies, do not charge users deposits. If the services can prove the necessity of charging a deposit, the deposit money must be put into a designated bank account and be subject to regulations aimed at preventing the misuse of funds. Thus, this study does not address user deposit problems.

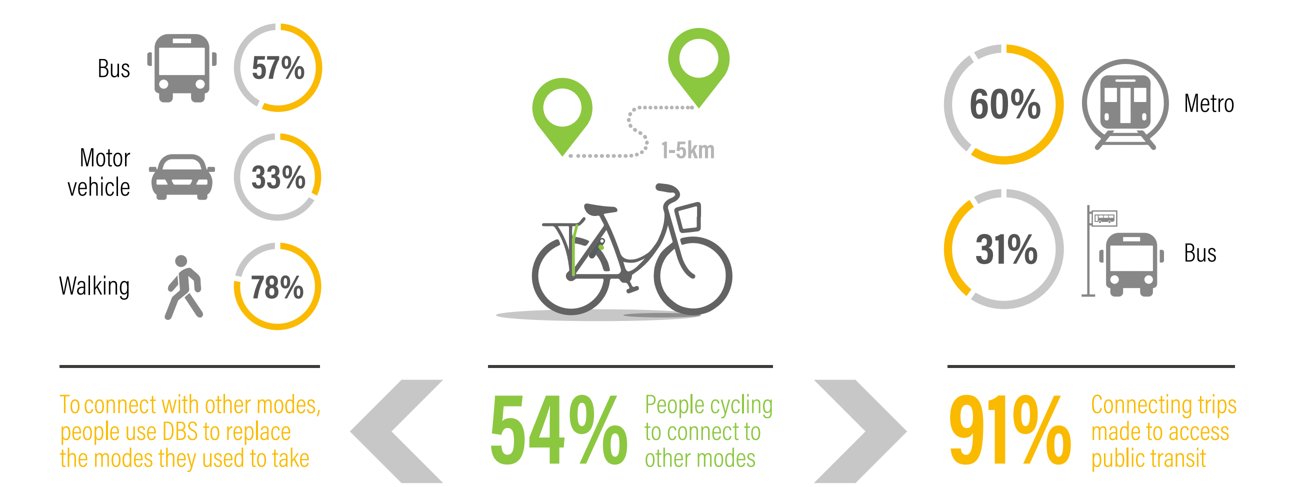
3.6 Travel Behavior Changed

Public transit could not provide door-to-door service, due to efficiency concerns. So the central concern in most cities has been to improve the connection to public transit and to build integrated transport systems. By cross-tabulating several survey questions, survey findings indicate that most people used DBS to connect to the public transit system, although DBS had largely replaced short trips finished by walking and taking buses. **The DBS system provides a primary solution to enhancing connectivity to public transit systems.**

According to the survey, 54 percent (n=3,727) of respondents used shared bikes to connect to other modes of transport. For those who used DBS to connect to other modes (Figure 3-8):

- 91 percent ride to connect to the public transit systems, including regular buses (31 percent) and metro (60 percent).
- 78 percent previously walked, 57 percent previously took a regular bus, and 33 percent previously took motorized vehicles to connect to public transit.

Figure 3-8 | Behavior Change Due to Use of Dockless Bikes



Notes: n = 6,902
Source: Survey results.

For short and medium trips, compared with walking and buses (relying on fixed bus schedules), people prefer cycling, as it is time-saving.

In most cities, motorized vehicles are overused for short-distance travel. For example, 39.3 percent of car trips are less than 5 kilometers in Beijing (BTI 2016). This means cycling has enormous potential for replacing motorized trips in cities. Based on the survey results (shown in Table 3-1), depending on the city, **17—45 percent of total dockless bike-sharing kilometers traveled replaced motorized kilometers traveled** (including private cars, taxis, ride-hailing, and motorcycles).

Moreover, bike-and-ride (combined use of bicycle and public transport for one trip) may also have the potential to replace long-distance private motorized trips. And these impacts, especially in terms of replacing private vehicle travel, may be underestimated, as the questionnaire is designed to understand the trips finished by DBS, rather than the entire travel chain in this report.

Furthermore, according to the results, travelers prefer to use dockless bikes since they believe cycling provides opportunities for health gains, as an environmentally friendly travel mode.

Table 3-1 | **Vehicle Kilometers Traveled Replaced by Dockless Bike-Sharing**

City	Total DBS VKT (km/wk)	VKT replaced by DBS in different modes (km/wk)			Motorized VKT replaced (%)
		Private car	Taxi and ride-hailing	Motorcycle	
Beijing	6,688	793	348	—	17.1
Shanghai	5,346	772	465	—	23.1
Guangzhou	4,105	200	720	252	28.6
Chengdu	6,039	549	1,111	350	33.3
Wuhan	4,394	344	615	407	31.1
Shenzhen	2,413	443	91	131	27.6
Nanjing	2,979	494	555	241	43.3
Jinan	2,623	375	468	316	44.1
Hangzhou	3,468	376	600	425	40.4
Xi'an	2,273	204	592	226	44.9
Lanzhou	2,559	241	438	59	28.8
Xiamen	1,693	73	270	251	35.1

Notes: 1. Total DBS VKT is calculated based on the travel distance DBS users estimated from survey analysis.
2. The VKTs of modal shift are calculated based on survey data collected in Figure 3-6, and applied as normalized mode share of each city. Cities' mode share data are collected from either official data or empirical studies.
3. VKTs of modal shift are calculated based on survey data and the mode share data of each city. Percentage of motorized VKT replaced = VKT replaced by DBS in different modes/ Total DBS VKT.
4. — = Not applicable.

Sources: Beijing Transport Institute 2019; Shanghai Urban and Rural Construction and Traffic Development Academe 2018; Guangzhou Transport Institute 2018; Chengdu Development and Reform Commission, n.d.; Meng 2017; Shenzhen Urban Planning and Land Resource Research Center 2017; Institute Nanjing Urban Planning and Transport Research 2019; *Shandong Transport News* 2012; Xiamen Transport Research Institute 2018; Z. Zhang et al. 2012; Shen 2018.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CHAPTER 4

IMPACTS ON HEALTH, CARBON, AND SAFETY

Cycling can bring multiple benefits to cities as it shifts motorized trips to zero-emission transport and increases physical activity. Also noteworthy is that health benefits from DBS cycling outweigh the risks of exposure to polluted air, and even road risks, in Chinese cities.

This section investigates the impacts associated with DBS cycling. By following the methodologies in Chapter 2, we quantified the following benefits and risks: physical activity benefit (avoided mortality), air pollution risk (mortality increased due to $PM_{2.5}$ exposure), carbon reduction (tons of CO_2 reduction), and crash risk (mortality increased). In addition, we assess the combined impact of physical activity and $PM_{2.5}$ exposure during cycling.

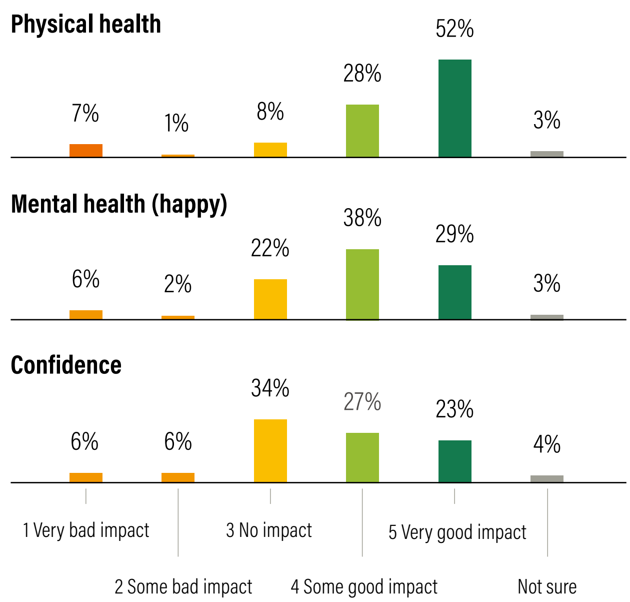
4.1 Health Impacts

Physical activity benefit

Findings from our perceptions survey questions show that most people (DBS users and nonusers) believe cycling is good for the health (Figure 4-1), as 80 percent believe cycling can lead to physical health benefit, 67 percent think cycling can improve mental health, and 50 percent say cycling makes them feel confident. Among all users, younger people tend to agree strongly that cycling makes them healthier. Older people tend to agree more that cycling could help boost confidence—31 percent of people over 45 years strongly agree that cycling makes them more confident. Physical activity can play an important role in managing mild to moderate mental diseases, especially depression and anxiety (Paluska and Schwenk 2000).

By adopting the dose-response functions (DRFs) in Figure 2-4 (Kelly et al. 2014; Tainio et al. 2016), we calculated the relative risks (RRs) of increased cycling activities. We also quantified the mortality avoided due to DBS cycling by following the methodologies mentioned in Chapter 2. Table 4-1 shows the RRs and the avoided mortality in samples from the 12 cities.

Figure 4-1 | **Users' Perceptions on Cycling and Health**



Notes: n = 8,218. The original survey question: How do you think dockless bike-sharing changes your life quality (in terms of the following aspects)? (From 1 to 5, 1 = Very bad impact; 3 = Neutral/ No impact; 5 = Very good impact)
- Physical health
- Mental health (happy)
- Confidence

Source: Survey results.

Table 4-1 | **Health Benefit of Physical Activity Due to Active DBS Cycling**

	Cycling duration (hours/week)	MET-hours/week	Relative risk	Mortality avoided in samples (number/year)
Shanghai	0.99	6.75	0.90	0.27
Beijing	1.23	8.34	0.89	0.30
Chengdu	1.38	9.38	0.88	0.24
Guangzhou	0.93	6.32	0.90	0.21
Shenzhen	0.94	6.42	0.90	0.19
Wuhan	1.06	7.23	0.89	0.21
Hangzhou	1.13	7.71	0.89	0.14
Xi'an	1.07	7.26	0.89	0.13
Nanjing	1.04	7.07	0.90	0.13
Jinan	1.08	7.36	0.89	0.12
Xiamen	1.04	7.09	0.90	0.08
Lanzhou	1.39	9.48	0.88	0.08
TOTAL (6,902 DBS users)				**2.09**

Notes: 1. Cycling duration was calculated based on DBS survey results.
2. MET intensity for cycling is assumed as 6.80 (Kahlmeier et al. 2017; Kelly et al. 2014; Tainio et al. 2016).
3. RR (cycling at 11.25 MET-hours/week) = 0.87 (95% CI 0.83–0.91)[15]; and the DRF is based on 0.5 power transformation (Kelly et al. 2014; Tainio et al. 2016).
4. Baseline mortality rate in China for age 15–64 years is 2.528 death per 1,000 population (United Nations 2019b).

Source: Authors' calculations based on survey results.

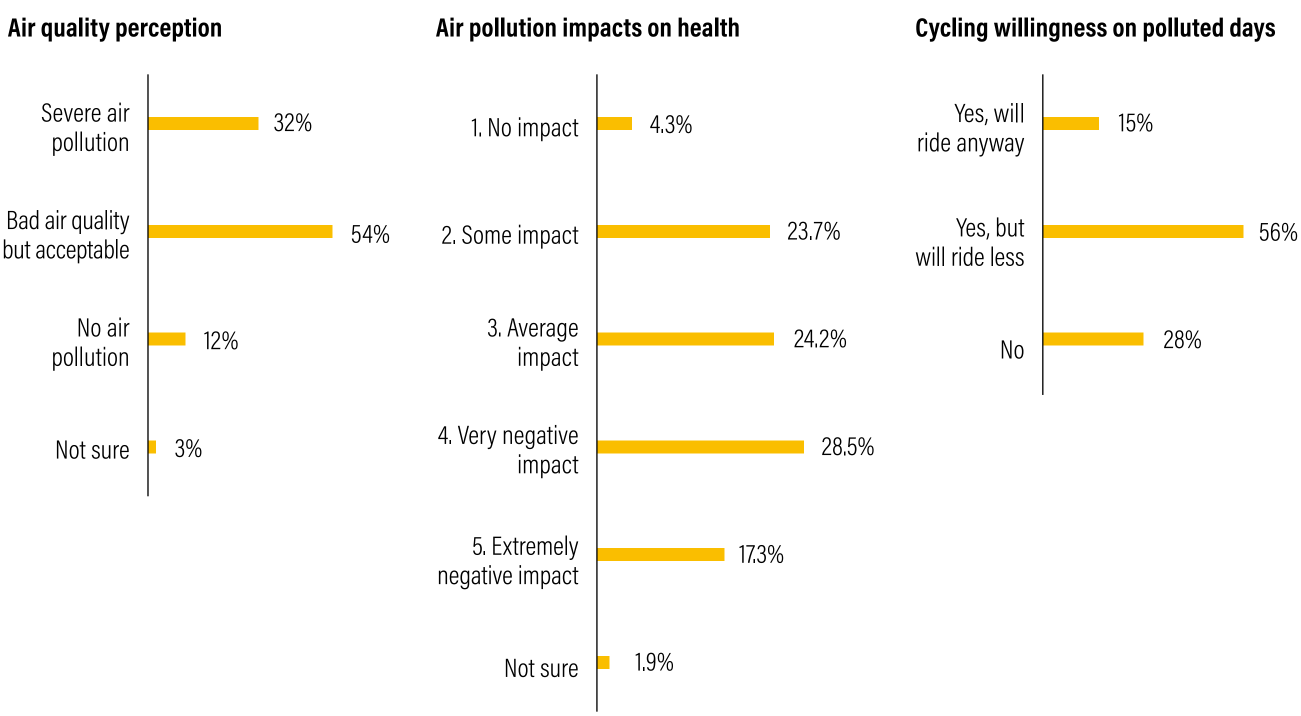
The total mortality avoided among 235 million DBS users in China would be 71,184 (95% CI 47,317–97,130), based on the assumptions that (1) cycling intensity and duration are similar across all Chinese cities, and (2) other influencing factors are not included. Actual health benefits from cycling could not always be as large as estimated if people cycle during days with worse air quality. Please see the following sections for further details.

Air pollution risk

Active cycling also increases inhalation of air pollutants, especially $PM_{2.5}$, leading to health risks such as premature deaths due to chronic obstructive pulmonary disease (COPD), ischemic heart disease (IHD), stroke, and lung cancer (WHO 2018b). Findings from the survey show that most DBS users are aware of the air quality issue in their cities and tend to cycle less during polluted days. People's opinions on cycling during polluted days indicated the following (see Figure 4-2):

- 86 percent realized the severity of air pollution.
- 46 percent agree that air pollution presents risks to health.
- 84 percent would either cycle less or stop cycling during bad air days.

Figure 4-2 | **People's Perceptions of Air Quality and Behavior Change on Cycling**



Notes: n = 8,218. Original survey questions:
1. What do you think of the air pollution situation in your city?
2. How do you think air pollution affects your health during cycling? (from 1 to 5. 1 = No impact; 3 = Average impact; 5 = Extremely bad impact)
3. Are you still willing to ride if there is air pollution?

Source: Survey results.

Table 4-2 | **Health Risk of $PM_{2.5}$ Exposure Due to Active DBS Cycling**

	Cycling duration (hours/week)	MET-hours/week	Background $PM_{2.5}$ ($\mu g/m^3$, Y2018)	Relative risk	Mortality increased in samples (Number/Year)
Shanghai	0.99	6.75	36	1.01	0.03
Beijing	1.23	8.34	51	1.02	0.05
Chengdu	1.38	9.38	51	1.03	0.04
Guangzhou	0.93	6.32	35	1.01	0.02
Shenzhen	0.94	6.42	26	1.01	0.02
Wuhan	1.06	7.23	49	1.02	0.03
Hangzhou	1.13	7.71	40	1.02	0.02
Xi'an	1.07	7.26	61	1.02	0.03
Nanjing	1.04	7.07	43	1.02	0.02
Jinan	1.08	7.36	52	1.02	0.02
Xiamen	1.04	7.09	25	1.01	0.01
Lanzhou	1.39	9.48	47	1.02	0.01
TOTAL (6,902 DBS users)					**0.03**

Notes: 1. Results of cycling duration are calculated from average duration and frequency from the DBS survey.
2. MET intensity = 6.80 (Kahlmeier et al. 2017; Kelly et al. 2014; Tainio et al. 2016).
3. Background $PM_{2.5}$ concentration data (2018) are from each city's Municipal Bureau of Ecology and Environment.
4. Baseline mortality rate in China for age 15–64 years is 2.528 death per 1,000 population (United Nations 2019b).
5. All other assumptions and sources are mentioned in Table 2-4.
Source: Authors' calculations based on survey results.

We adopted the methods mentioned in Table 2-4, and calculated RRs and the increased mortality due to $PM_{2.5}$ exposure during cycling in the 12 cities (see Table 4-2).

The total mortality increased among 235 million DBS users in China would be 10,293 (95% CI 5,991–13,076), based on the assumptions that (1) all DBS users are exposed to similar $PM_{2.5}$ concentrations, and (2) other influencing factors are not included. This health risk might be outweighed by the health benefits of cycling. However, this would only occur under a certain level of $PM_{2.5}$ concentration and under certain durations of cycling (Tainio et al. 2016). Please refer to the following section for details.

Combined health impact of cycling and air pollution

We used the methods and assumptions from Chapter 2 and calculated RRs for the combined effect of cycling activities and $PM_{2.5}$ exposure for the 12 cities. We then applied the comparative risk assessment (CRA) method and translated RRs to mortality changes attributable to the combined effect. In addition, we adopted the concept of the "tipping point" and the "break-even point" (Tainio et al. 2016), and recommended the suitable cycling duration for each city under the average $PM_{2.5}$ concentration. At the **tipping point,** maximum health benefit has been reached; beyond that point, additional cycling duration will not increase benefits. Increasing cycling will lead to the **break-even point**, where the risk from air pollution starts outweighing the benefit of cycling activity (above a certain level of $PM_{2.5}$ concentration); beyond this point, additional cycling will damage health.

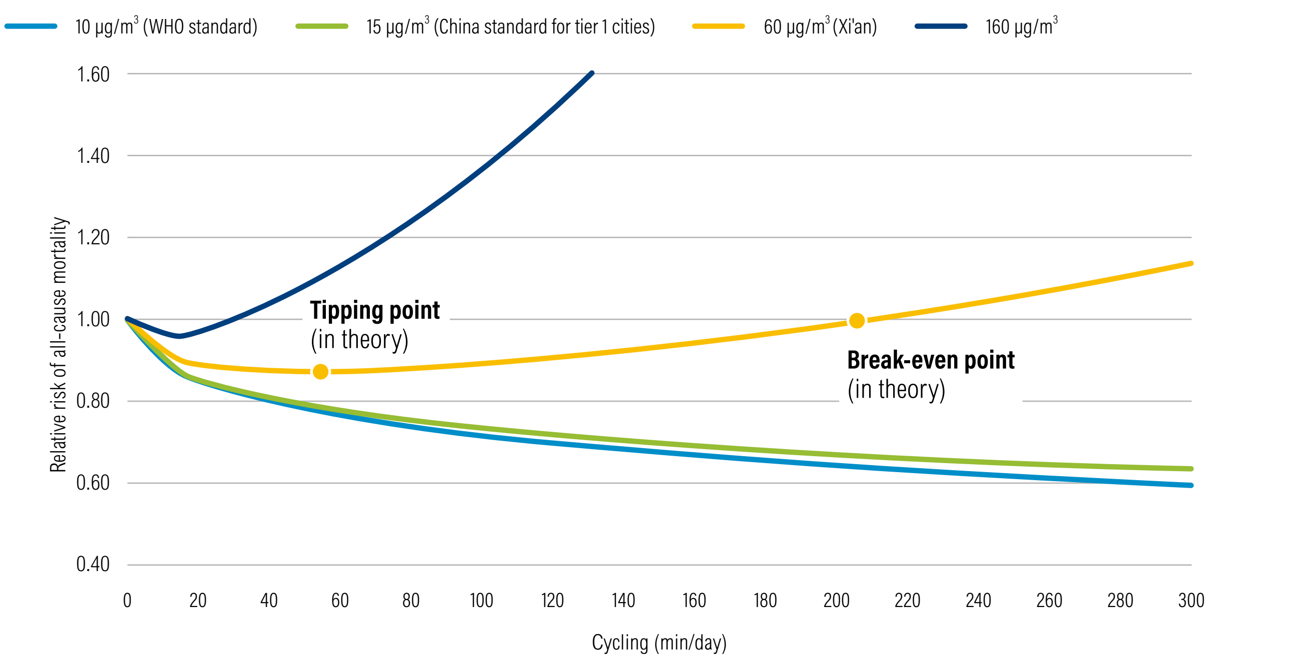
Table 4-3 and Figure 4-3 shows the net health impact from the combined effect of cycling activity and $PM_{2.5}$ pollution. The net health impact is expressed by the change in number of mortalities within DBS user samples in the 12 cities. Net mortality avoided among a total of 235 million Chinese DBS users would be **59,635** (95% CI 33,181–90,142), assuming most users are exposed to a similar level of $PM_{2.5}$ concentration and have similar physical activity patterns. For most cities with the average $PM_{2.5}$ approximately 50-60μg/m³, one hour of cycling per day could deliver the maximum health benefit if there are no other influencing factors.

Table 4-3 | **Net Health Impact of the Combined Effect of DBS Cycling and $PM_{2.5}$ Exposure**

	Average $PM_{2.5}$ ($\mu g/m^3$)	Exposed DBS users	Relative risk	Mortality changed in samples (Number/ Year)	Tipping point in theory (Min/Day)	Break-even point in theory (Min/Day)
Shanghai	36	942	0.91	0.24	150	615
Beijing	51	943	0.91	0.24	75	300
Chengdu	51	697	0.90	0.19	75	300
Guangzhou	35	738	0.91	0.18	150	615
Shenzhen	26	683	0.91	0.17	300	—
Wuhan	49	706	0.91	0.17	75	300
Hangzhou	40	441	0.91	0.12	120	465
Xi'an	61	445	0.92	0.10	60	195
Nanjing	43	427	0.91	0.11	90	375
Jinan	52	386	0.91	0.09	75	300
Xiamen	25	261	0.90	0.07	300	—
Lanzhou	47	233	0.90	0.06	75	300
TOTAL (6,902 DBS users)		**6,902**		**1.75**		

Note: — = Not applicable.
Sources: Authors' calculations based on survey results

Figure 4-3 | **Relative Risks for the Combined Effect of Cycling and $PM_{2.5}$ Concentration: Tipping Points and Break-Even Points**



Notes: 1. The curve of the DRF of Xi'an represents the highest $PM_{2.5}$ level in the 12 cities (60 $\mu g/m^3$); while the curve of the 160 $\mu g/m^3$ represents the threshold where cycling more than 30 minutes/day is NOT recommended.
2. The curves are based on data from the DBS survey, Tainio et al.'s research (2016), and air quality standards (WHO 2006; MEE 2012).
3. The tipping point and break-even point for Xi'an are marked in the figure.
Source: Authors' calculations based on data from Tainio et al. 2016; WHO 2006; MEE 2012.

The findings show that in theory, 30 minutes of cycling per day will lead to net health benefits in most cities with the average background $PM_{2.5}$ under 160µg/m³. However, cycling more than 30 minutes at this air pollution level or above should be avoided because beyond this threshold, benefits from additional physical activity (PA) will be outweighed by the risk of bad air inhaled. In theory, any levels of PA are recommended in cities that meet either WHO's (10µg/m³) or China's air quality standards (15µg/m³) (WHO 2006; MEE 2012).

4.2 Carbon Reduction

Based on the method mentioned in Chapter 2, we estimated CO_2 reduction due to the modal shift to DBS cycling (Table 4-4). Although most people in the 12 cities tend to use DBS to replace walking and bus trips (Chapter 3), kilometers avoided from private motorized trips are still worth noting. Since private motorized vehicles (especially private cars) are responsible for the major share of urban transport emissions, any avoided kilometers could contribute to efficient carbon mitigation and better air quality.

Findings show that most emission reductions from the DBS-related mode shift are not as significant as expected, mainly because most people like to use DBS for short-distance trips that were previously finished by walking and bus. Our calculations prove that the reduction of air pollutants (e.g., $PM_{2.5}$) is far from significant due to short traveled distance replaced by DBS, and cars are not the main contributors of $PM_{2.5}$, thus, we chose not to show those results. Only CO_2 reduction from DBS-related behavior change is significant enough to warrant attention. The total nationwide CO_2 reduction from DBS users would reach 4.8 million tonnes annually, if all 235 million Chinese users were to keep a similar mode shift pattern as described in Chapter 3.

4.3 Road Crash Risk

As vulnerable road users, cyclists travel with a higher risk of road crash–related injury than drivers. Survey results on people's perceptions

Table 4-4 | **CO_2 Reduction Due to DBS Usage**

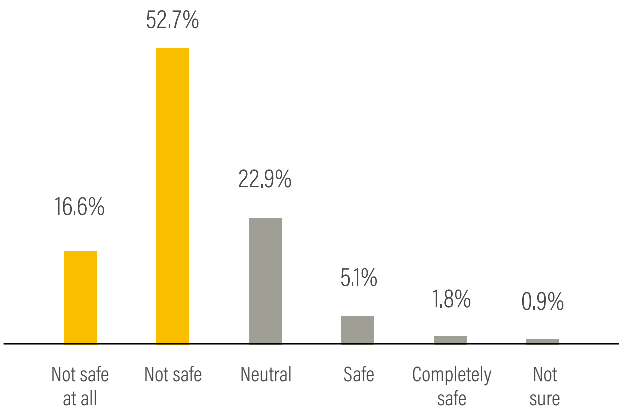
	Distance replaced: private car (km/wk)	Distance replaced: taxi and ride-hailing (km/wk)	Distance replaced: motorcycle (km/wk)	CO_2 reduction in samples (tonne/wk)	CO_2 reduction in samples (tonne/yr)
Shanghai	772	465	0	0.26	13
Beijing	793	348	0	0.24	12
Chengdu	549	1,111	350	0.41	22
Guangzhou	200	720	252	0.26	14
Shenzhen	443	91	131	0.13	7
Wuhan	344	615	407	0.25	13
Hangzhou	376	600	425	0.24	12
Xi'an	204	592	226	0.20	11
Nanjing	494	555	241	0.25	13
Jinan	375	468	316	0.22	11
Xiamen	73	270	251	0.11	6
Lanzhou	241	438	59	0.16	9
TOTAL (6,902 DBS users)	**4,863**	**6,271**	**2,658**	**2.73**	**143**

Note: Assumptions:

1. All private cars and motorcycles use gasoline.
2. All taxis in Chengdu, Wuhan, Jinan, Xi'an, and Lanzhou use natural gas; while all taxis in Shenzhen are powered by electricity. Taxis from other cities use gasoline.

Sources: Replaced distances were calculated from data obtained from the DBS survey and the city's mode split data used in Table 3-1.

Figure 4-4 | **Do You Feel Safe When Cycling? (From 1 to 5; 1 = Not at all; 5 = Completely safe)**



Note: n = 8,218.
Source: Survey results.

about the safety of cycling on the streets show that about 70 percent do not think urban roads are safe enough for cycling; results in the 12 cities show similar trends (see Figure 4-4). Additionally, a survey of people's attitudes toward other road-related dangers is discussed in Section 5.3.

Due to lack of categorized bike fatality and activity data at the city level in China, the road crash risk is estimated at the national level and does not distinguish between DBS and other types of cyclists. National cyclist fatalities are calculated based on reported numbers from WHO's "Reported Distribution of Road Traffic Deaths by Type of Road User—Data by Country" and "Global Status Report on Road Safety 2018" (WHO 2016, 2018a).

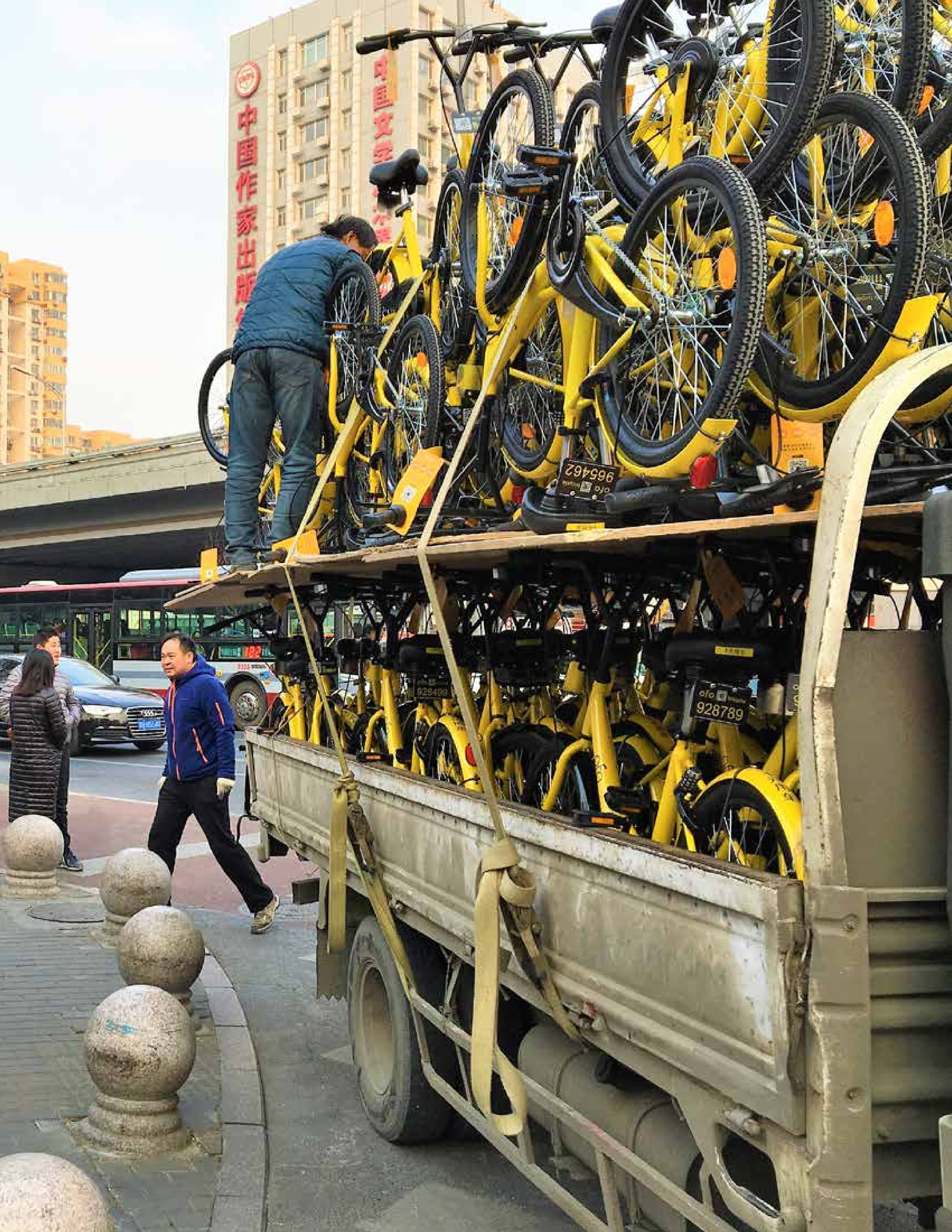
The average trip distance collected through the user survey is used to estimate annual DBS fatalities in Chinese cities following the methodology developed by WHO. The adopted methodology is described in Section 2.3. Key indicators and results are listed in Table 4-5.

Based on the methodology above, 15,556 (95% CI 14,669–16,443) out of 20,751 bike fatalities in 2018 were attributed to DBS, according to its traveled mileage share. It is worth noting that we used data from an empirical study on users' preference of DBS over other modes in the first/last-mile connection to approximate the share of DBS among all cyclist trips (Fan et al. 2019). However, other studies show that DBS is the most appealing mode for transfer compared with other situations (Li et al. 2019). Therefore, the share of DBS might be overestimated, as are DBS fatalities. These results could be updated when more empirical data are available.

Table 4-5 | **Key Indicators in Calculating Bike Fatalities**

Indicators	Results	Sources and Assumptions
Bike fatalities	20,751	• We assumed that exposure risks of private cyclists and DBS users are the same. • We assumed that the distribution of road traffic fatality by type of road users in 2018 is the same as in 2013, due to data unavailability. • Road traffic fatalities are 256,180 (WHO 2018a). • Cyclist fatality share is 8.1 percent of all road fatalities (WHO 2016).
Bike trips	206,005,857	• We assumed that bike users are urban population age 15–65 and the age distribution in urban and rural areas is the same. • Urban population is 591,970,854 (National Bureau of Statistics of China 2018). • Average trips per person per day (trip rate) is 3 (Kahlmeier et al. 2017). • Cycling mode share in Chinese cities is 11.6 percent (Fan et al. 2019).
Bike kilometers traveled	618,017,572	• Average bike trip distance is 3 km (Ibold and Nedopil 2018).
DBS kilometers traveled	463,287,874	• Average DBS bike trip distance from our survey results (2.6 km). • Share of DBS trips (out of all cycling trips) is estimated as 87.7 percent (95% CI 82.7%–92.7%) (Fan et al. 2019).
DBS fatalities	15,556	

Sources: Survey results; WHO 2016; WHO 2018a; National Bureau of Statistics of China 2018; Kahlmeier et al. 2017; Fan et al. 2019; Ibold and Nedopil 2018.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CHAPTER 5

REGULATION REVIEW AND IMPLICATION

To alleviate curb obstruction and safety issues caused by the surplus or disproportional distribution of DBS, Chinese cities have introduced several innovative management measures in three main categories: fleet management, parking management, and facilities planning and implementation.

5.1 Challenges and Policy Background

Surplus in the market resulted in an increase in fleet sizes, curb obstruction, and safety issues. A vast number of unused or broken bikes have been abandoned on streets or impounded in vacant lots in many big cities, as too many bikes were introduced with few restrictions. Thus, for the cities that have introduced or plan to introduce DBS service to promote cycling without causing chaos in urban built-environments, DBS fleet management, parking management, and facilities planning and implementation are the priorities.

To address the problems, China's Ministry of Transport (MoT) drafted the first bike-sharing national-level regulation in May 2017, and issued a formal regulation in August. Till the end of 2018, 39 Chinese cities have passed local imperatives to guide market entry, operation, and maintenance of the bike-sharing system, adhering to national guidelines (Wang 2018). Cities have also adopted a series of policies to regulate the bike fleet size, bike parking on the streets, and cycling facilities.

To better understand the regulations and their implementation in the 12 cities, a score-based indicator system was developed in this research. This study evaluates cities' DBS regulations on **fleet size control, bike parking management,** and **cycling infrastructure improvement.** Table 5-1 shows how cities perform on those three criteria: cities are marked with a score of one for implementing improvement measures required in regulatory documents. As a result, among the 12 studied cities, Beijing, Shenzhen, Guangzhou are recognized as providing the best policy environment for shared bikes due to their holistic and explicitly stated regulations. Additionally, based on the policies reviewed for the 12 cities, a brief DBS management stakeholder landscape is summarized (see Box 5-1) to help understand the main responsibilities of regulation and enforcement bodies in Chinese cities.

Box 5-1 | DBS Management Stakeholder Landscape

Given the rapid development of DBS in Chinese cities, most cities have built a DBS management group led by the local Transport Commission to share responsibilities to support sustainable and regulated development of DBS.

As shown in Figure B5-1, the Transport Commissions primarily lead the coordination with other management authorities and deploy regulations and guidelines/tools on fleet control, parking management, dedicated facilities, etc.

To support the regulations and guidelines, urban management is required to avoid disorderly bicycle parking, and the traffic police department is made responsible for dealing with traffic violations involving shared bicycles. District-level governments are responsible for facilities planning and implementation based on the approved DBS fleet in localities. To cooperate with the implementation, the district government also needs to inspect DBS parking activities to support KPI assessment in cities.

Figure B5-1 | Key DBS Management Stakeholders and Main Responsibilities in Chinese Cities

Key DBS management stakeholders and responsibility		
City-level authorities	**Transport Commission** • Lead coordination • Publish DBS regulatory guidance on fleet control, parking management, dedicated facilities, etc.	
	Urban management commission • Enforces penalties against DBS operators for improperly parked bikes on curb	**Traffic police** • Handles bike registration • Regulates improper parking and cycling user behavior
District-level authorities	**District government** • Inspect improper distributed/parked bikes, disqualified bikes, etc. • Planning and implementation of dedicated facilities; e.g., parking areas, bike lanes, etc. • Cooperate with public security department on emergency response/event	
Players	**DBS operators** • Cooperate with regulation	**DBS Users** • Cooperate with regulation

Notes: This figure is summarized based on the local DBS Implementation Plans.
Source: Chengdu Municipal Commission of City Management 2018; Shenzhen Municipal Commission of Transport 2019; Hangzhou Municipal Commission of Transport 2018.

Table 5-1 | **Policy Review on Fleet Size Control, Bike-Parking Management, and Cycling Infrastructure Improvement for Twelve Cities**

Criteria				Score
Fleet size control	Market entry	Dedicated regulations/guides on market entry		1
		Bidding mechanism introduced on permit granting/renewal		1
	Fleet size management	Requirements on fleet size limit		1
		Requirements of detailed data-sharing format		1
		KPI system used to determine operator's permit renewal/fleet size		1
		Penalties specified for operators due to breaches of fleet size requirement		1
	Subtotal			**6**
Parking management	Parking area regulation	Technical guides of bike parking area setting and design		1
		Clarified dedicated and prohibited parking areas for dockless bikes		1
		Requirements on parked bikes (e.g., number of bikes in a parking lot, upright parking)		1
		Requirements on smart bike–parking facilities (e.g., dual-height racks, underground parking vaults, etc.)		1
	Subtotal			**4**
	Enforcement	Enforcement regulations for shared bike breaches		1
		On operator	Penalties specified for operators due to poor distribution	1
			Parking management considered a major KPI of the operator's performance	1
			Staffing required on parking management	1
		On user	Operators allowed to charge additional distribution fees on users if they didn't park the bikes in preferred locations	1
			Geofence parking required to enable proper parking	1
			Personal credit system used to adjust riding fare based on user's parking behavior	1
	Subtotal			**7**
Facilities	Plans for bike lanes network expansion			1
	Dedicated bike facility (e.g., bike highway, underground parking vaults)			1
	Cycling facilities improvement specified in street designs			1
	Subtotal			**3**
	Total			**20**

Notes: This table summarized open published DBS regulations at the city and national levels, as well as city-level nonmotorized transport plans after dockless bikes entered Chinese cities; that is, April 2016 to October 2019.
Sources: The sources of regulatory documents are listed in Appendix II.

	Beijing	Shanghai	Guangzhou	Shenzhen	Wuhan	Hangzhou	Xiamen	Xi'an	Chengdu	Jinan	Nanjing	Lanzhou
										1		
			1									
	1	1	1	1	1	1	1	1	1	1	1	1
	1		1	1	1	1	1		1	1		1
	1	1	1	1	1	1	1		1		1	
	1	1		1	1							
	4	**3**	**4**	**4**	**4**	**3**	**3**	**1**	**3**	**3**	**2**	**2**
	1	1	1	1		1	1		1	1		
	1		1	1	1		1	1	1	1	1	1
	1		1	1					1			
	1		1	1								
	4	**1**	**4**	**4**	**1**	**1**	**2**	**1**	**3**	**2**	**1**	**1**
	1	1		1	1							
	1	1		1	1							
	1	1	1	1	1	1	1		1		1	
		1		1	1	1	1	1			1	1
	1		1	1	1		1			1	1	
	1	1	1	1	1	1	1	1	1	1	1	1
	1	1	1	1		1	1	1	1	1	1	1
	6	**7**	**4**	**7**	**6**	**4**	**5**	**4**	**3**	**3**	**5**	**3**
	1	1	1	1	1			1		1	1	1
	1						1		1			
	1	1	1									
	3	**2**	**2**	**1**	**1**	**0**	**1**	**1**	**1**	**1**	**1**	**1**
	17	**13**	**14**	**16**	**12**	**8**	**11**	**7**	**10**	**9**	**9**	**7**

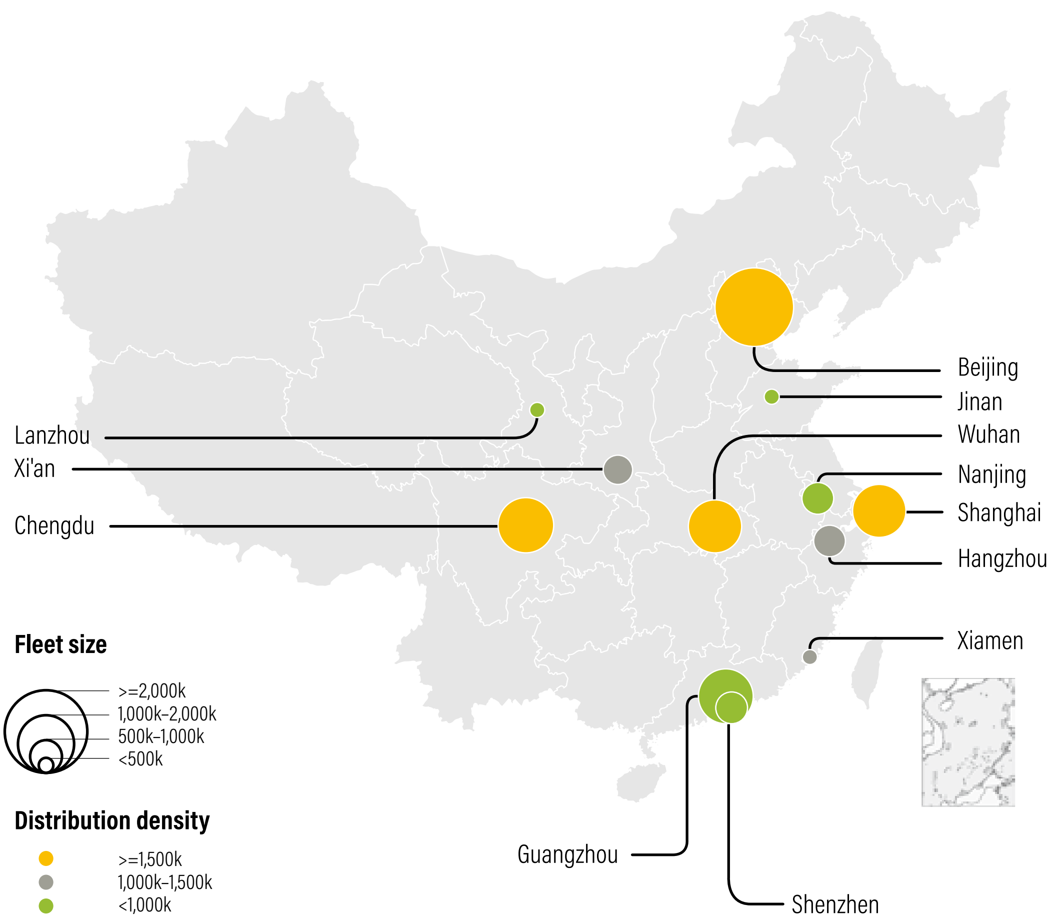
5.2 Fleet Size Control

In 2017, the number of dockless shared bikes in China was estimated at 23.0 million during the peak of the market, operating in over 200 Chinese cities. Although the fleet dropped to 19.5 million in late 2019, the DBS service has been operating in 360 Chinese cities, and the total registered user number has increased as well (CAICT 2019; State Information Center 2018). Cities have been improving regulations to reduce fleet numbers in cities to a more rational level, without hampering accessibility.

The challenge of oversupplied bikes depends on both total fleet size and distribution density in urban built-up areas, and this problem was exacerbated in 2017–2018 when the DBS fleet reached its peak in cities. As illustrated in Figure 5-1, big cities, led by Beijing, showed both extremely large fleet size and high density of DBS bikes. Smaller cities, such as Hangzhou, Xi'an, and Xiamen, have seen far fewer DBS bikes with lower distribution density, yet the regulation and service pressure in the urban area was still high.

One of the leading solutions for oversupplied bikes in cities (*CCTV News* 2017) is managing the overall fleet size by capping it and setting up a performance-based evaluation. To provide

Figure 5-1 | **Peaked DBS Fleet Size and Distribution Density in the Twelve Cities, 2017–2018**



Notes: 1. Distribution density = Fleet size/Area of built district (km^2), where the area of built district is the operating area for DBS companies.
2. Cities built-area based on 2017 Urban Construction Yearbook (2017) by MoHURD.

Sources: Bicycle Fan 2019; Yu 2019; Jiang 2018; Wu 2019; Wuhan Broadcasting Station 2018; Zhejiang News Broadcasting 2019; Qianzhan Industry Research Institute 2019; Xiao and Zhang 2018; *Xinmin Evening News* 2019; Xi Wang 2019; Hbspcar 2018; J. Xu 2018; Ministry of Housing and Urban-Rural Development of China 2017; P. Yin and Zhou 2016; *CCTV News* 2019; *Xinhua News* 2019; Xia 2019.

Table 5-2 | **Comparisons of the Current Fleet to the Peak in Cities**

City	Peak fleet size (thousands)	Date	Most current fleet size (thousands)	Date	Fleet decreased
Beijing	2,350	8/2017	900	11/2019	62%
Shanghai	1,700	9/2017	500	1/2019	71%
Guangzhou	1,000	2017	400	2/2019	60%
Shenzhen	890	12/2017	480	6/2019	46%
Wuhan	1,030	6/2018	750	4/2019	27%
Hangzhou	770	3/2018	390	1/2019	49%
Xiamen	460	12/2017	150	2/2019	67%
Xi'an	730	11/2017	450	3/2019	38%
Chengdu	1,800	9/2017	700	1/2019	61%
Nanjing	638	3/2018	317	4/2019	50%
Jinan	180	1/2018	—	—	—
Lanzhou	290	12/2018	—	—	—

Note: Lanzhou and Jinan have not shown a decrease in DBS fleet size based on available sources.
— = Not applicable
Sources: Bicycle Fan 2019; Yu 2019; Jiang 2018; Wu 2019; Wuhan Broadcasting Station 2018; Zhejiang News Broadcasting 2019; Qianzhan Industry Research Institute 2019; Xiao and Zhang 2018; *Xinmin Evening News* 2019; Xi Wang 2019; Hbspcar 2018; J. Xu 2018; Ministry of Housing and Urban-Rural Development of China 2017; P. Yin and Zhou 2016; *CCTV News* 2019; *Xinhua News* 2019; Xia 2019.

a reasonable capped fleet, cities have started to estimate a recommended fleet size based on either demand or supply, such as existing operation turnover rate, population in the built district, existing bike parking areas, etc. Unlike most Chinese cities that have focused on capping the maximum number of a fleet, Jinan and Guangzhou's exercise of controlled entry may shed light on cities with a not yet saturated DBS fleet. Jinan published its dedicated market entry regulations (*Regulations on Market Entry for Bike-Sharing Operators*), while Guangzhou introduced a bidding mechanism for granting permission to determine the qualifications of DBS operators.

Most of the cities have restricted the maximum number of DBS bikes, to address the oversaturated market. As shown in Table 5-2, Beijing, Guangzhou, and Chengdu have reduced about 60 percent of bikes from their peak in late 2017 and continued to reduce the DBS fleet size (Fan 2018). The Shanghai and Xiamen governments undertook more stringent measures to control the total DBS fleet, resulting in a almost 70 percent decrease in DBS fleets.

To further control the fleet size and improve the service quality of DBS, seven cities introduced a **key performance indicator (KPI) based system** to evaluate the operator's performance; results affect permit renewal and fleet size adjustments. In general, the main KPIs include vehicle quality, operation and distribution, parking management, and public satisfaction.

However, most cities lack sufficient regulations on market entry or stringent enforcement on DBS fleet size and should consider the following:

- Many cities lack dedicated regulations on DBS market entry to assess qualifications of DBS operators and grant/terminate permissions. With uncontrolled fleet distribution on urban streets, cities will not only face the issue of DBS bikes cluttering and obstructing streets, but also huge numbers of bike retirements. Since many cities required DBS bikes to be scrapped after three-year usage, a huge number of DBS bikes need to be retired in 2019–2020. Estimated by Mobike, formerly the largest bike-sharing company, the retired fleet in 2020 would reach

10 million in China, which would produce 0.16 million tonnes of scrap metal (MoT 2018). Both national and local governments need to provide **clear guidelines on market entry and take bicycle retirement/recycling** into consideration.

- Besides big cities such as Beijing, Shanghai, and Guangzhou, many other cities still need to establish **reasonable methodologies to estimate total DBS size.** They need guiding tools/documents to assess the need and supply of DBS in urban settings, and to provide rational fleet distribution for the entire service area in cities, as well as for different locations (e.g., central urban areas, suburban areas, public transit stations, etc.).
- KPIs could serve as a great assessment tool to improve the quality of DBS service. The current indicators mainly include vehicle quality, operation and distribution, parking management, and public satisfaction. To avoid an oversaturated supply resulting from irrational market competition, the **DBS turnover rate, operators' financial sustainability, and DBS bike life cycle should be overseen by KPI assessment** to ensure functional development of the market.
- The requirement of **data-sharing** varies among cities, in terms of the requirements of real-time data, inventory lists, and the frequency of data updating. Better quality and standardized data could enhance strong management and enforcement. For example, Shenzhen has a relatively holistic requirement for data collection and the operator's data platform, which should be able to alert users and operators to remove wrongly parked bikes promptly by locating GPS information.
- Due to serious problems faced by DBS fleets in many cities, DBS fare prices have increased and been comparatively higher than for buses. Besides setting limitations for DBS operators, locals should **provide certain incentives to DBS operators** to allow them to maintain profitability while providing affordable and quality service to the public.

Box 5-2 | KPI-Based Performance Assessment Regulation

Starting with Xiamen and Chengdu, Chinese cities have adopted KPI-based systems to evaluate the operator's performance. Thus, the final performance score affects permit renewal and fleet size adjustments.

Most cities approach parking regulations as a management issue. In 2017, along with the general Assessment Measures, the Chengdu City Management Commission released dedicated Assessment Measures for DBS parking, indicating that a district-level assessment should be conducted monthly (Chengdu Municipal Commission of City Management 2018). This measure includes several main parking performance management topics, such as maintenance and operations, parking performance on different types of roads, emergency response, etc., which adds up to 54 indicators. It also requires operators to manage improper parking on curbs within 30 to 50 minutes (depending on road type) as daily practice or operators face a fine from the city management bureau/commission. As a result, the operator that scores lowest three or four times in a year would face penalties, such as a decrease in the fleet, lower credits, or suspension of service in the city. Also, the monthly results would be open to the public through local media. Benefiting from these regulations, DBS daily trips reached over 2 million and turnover rate increased by 1.9 times/day in May 2019 (Chengdu Daily 2019)—much higher than Beijing and Shanghai's rate.

Moreover, cities also changed the weight of the indicators to guide operators, based on the change in management focus. In 2017 the Hangzhou government used the performance score to reduce the fleet size of poor-performing operators, resulting in a 0.5 million bike reduction in 2018 (Tong 2019). After reducing the fleet size to a reasonable number, the indicators were weighed to allocate the share of new bikes among the operators. In September 2019, Beijing Municipal Commission of Transport posted the half-year DBS assessment report, which requested a fleet size reduction totaling 0.38 million. Moreover, it mentioned that real-time data-sharing and the quality of data would become key indicators for the next phase of assessment (Beijing Municipal Commission of Transport 2019).

5.3 Parking Management

Based on survey results on dockless shared bike parking (Table 5-3), most people believe bike parking obstructs on-street parking and sidewalk space. Citizens in larger cities like Beijing and Shanghai, which introduced the DBS system at an early stage with too many bikes, tend to have lower tolerance toward the disorder and danger caused by unregulated DBS parking.

Parking management is based on setting parking area standards and taking strong enforcement action to manage both operators and users.

Guangzhou, Shenzhen, and Beijing have more holistic and clarified regulatory solutions on **parking area management on sidewalks and public spaces.** These cities have dedicated technical standards on setting parking areas on sidewalks, and specifying the parking area design by locations. For example, Guangzhou's bike parking guidelines indicate parking areas should be set in the facility zone on the sidewalk, and no parking area should be set when sidewalk width is less than 3.5 meters (Figure 5-2). The pedestrian passage should be no less than 2 meters wide (Guangzhou Municipal Transportation Bureau 2017). Also, detailed design is provided

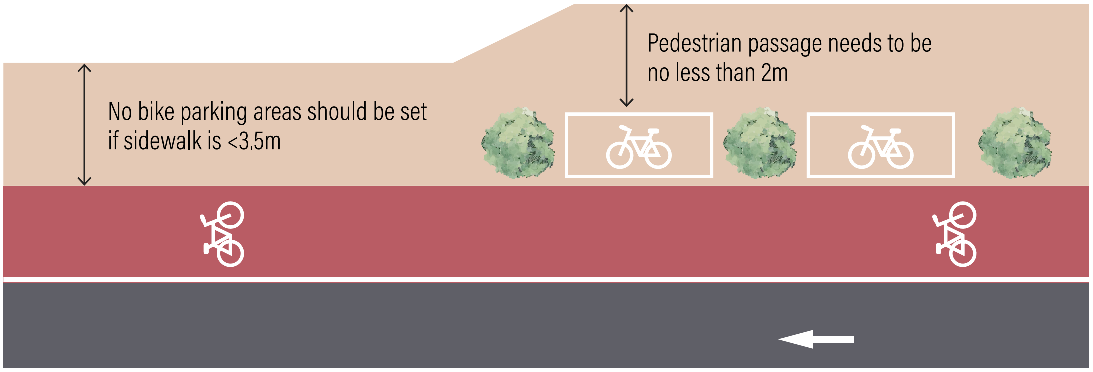
Table 5-3 | **People Who Believe DBS Has Bad or Extremely Bad Impacts in the Listed Situations**

More than 40% | 30-40% | Less than 30%

	Block vehicle parking space (%)	Block sidewalks (%)	Disorder cityscape (%)	Block metro stations (%)	Block bus stops (%)	Block carriageways (%)
Beijing	48	45	39	37	34	24
Shanghai	45	43	39	36	32	23
Hangzhou	42	38	40	32	29	22
Guangzhou	42	39	36	28	29	22
Xi'an	40	36	38	27	28	21
Xiamen	39	35	36	21	27	21
Wuhan	39	32	33	23	28	23
Shenzhen	37	34	33	20	23	18
Chengdu	37	29	30	27	26	22
Nanjing	37	26	27	25	20	17
Lanzhou	30	21	24	N/A	18	19
Jinan	25	18	17	N/A	18	11

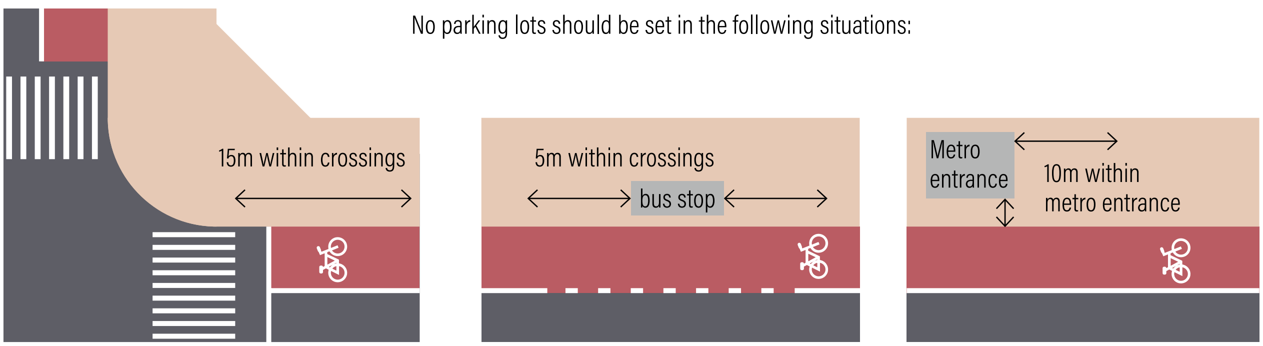
Notes: 1. The original survey question is What problems do you think dockless shared bikes pose to your city? (n = 8,218) (scaling from 1 to 5; 1 = No impact; 3 = Average impact; and 5 = Extremely bad impact).
2. The table shows the percentage of people who believe DBS generates negative impacts (i.e., people selected either 4 or 5 in this question) out of total.
Source: Survey results.

Figure 5-2 | **The Minimum Sidewalk Requirement by Guangzhou's Bike Parking**



Notes: Redrawn based on Guangzhou's bike parking guides (drawing not to scale).
Source: Guangzhou Municipal Transportation Bureau 2017.

Figure 5-3 | **The Requirements of Bike Parking Area Setting at the Intersection (left), Bus Stop (middle), and Metro Entrance (right) by Guangzhou's Bike Parking**



Notes: Redrawn based on Guangzhou's bike parking guides (drawing not to scale).
Source: Guangzhou Municipal Transportation Bureau 2017.

for locations such as intersections, bus stops, and metro stations to prevent blocking of pedestrian passage (Figure 5-3). Moreover, regulations specify how bikes should be placed in a parking area, such as clarifying the capacity of a labeled parking area and requirement to park bikes upright. Moreover, those three cities required smart bike parking facilities (e.g., dual-height racks, underground parking vaults, etc.) to increase capacity.

Enforcement responsibility and penalties for violations byDBS operators and users are clarified in some cities. For example, in Wuhan, Beijing, and Shanghai, the *Non-motorized Management Regulation/Shared Bikes Management Regulation* listed possible penalty fees for not keeping clear of the prohibited parking area and was to be enforced by local urban management authorities. Also, parking management is regarded as a major KPI of the operator's performance. Operators with higher performance can increase their fleet size, and vice versa. At the same time, DBS operators have worked with public authorities using virtual mapping and geofencing technologies to monitor and regulate users' parking behavior. Users' violations would incur an additional distribution fee/penalty fine of ¥5 (D. Zhang 2018), and they would risk not being able to use the service on low personal credits on DBS apps in most cities with DBS services.

After coordinating with DBS operators, some district-level governments and urban management sectors initiated several DBS fleet management pilots that have appeared to be effective. For example, Beijing's Dongcheng District selected several key neighborhoods with high commercial and residential use, dividing the streets into four sections and letting DBS companies manage all dockless shared bikes in their areas of responsibility, instead of managing their own fleets in the entire neighborhood. This construct enormously decreased pressure on operation and parking management on both sides (Yu 2019).

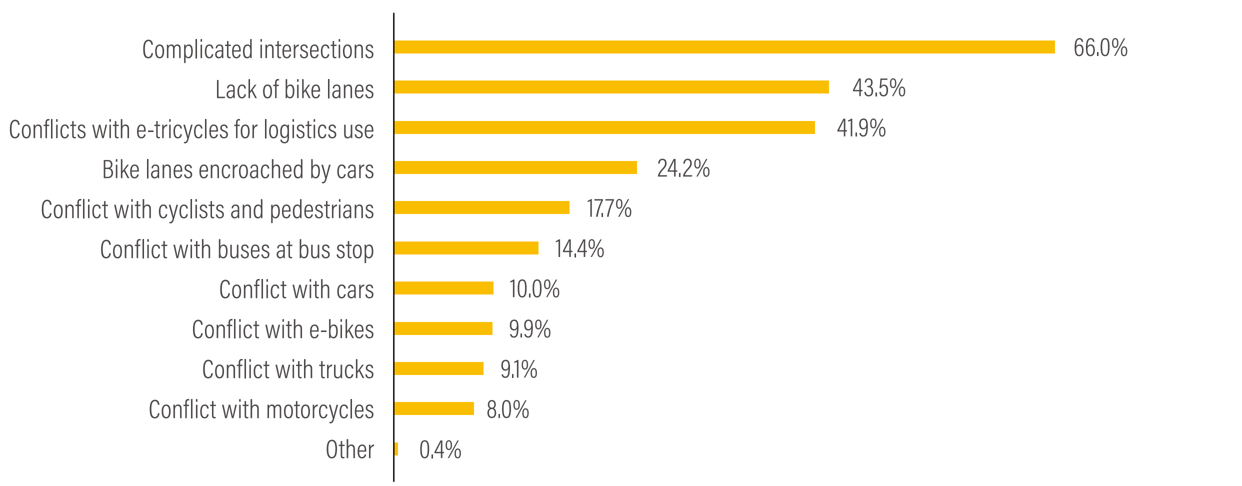
However, parking management needs more enablers to increase its cost-efficiency.

- In most cities, operators are mainly responsible for breaches of parking. To lower the risks on user parking violations, operators are authorized to charge additional fees to users for not parking correctly, yet the fees vary among cities. Thus, a **reasonable distribution charge should also be determined by the government** and, preferably, reflected in the KPI on operators' performance assessments.
- Introducing new technologies, such as geofence, e-license, and real-time data-sharing systems could enhance the efficiency of parking management and save the labor costs of both public sector and operators. Cities should encourage the **standardized technologies application** proactively; for example, Beijing has piloted a dedicated technique standard on geofencing applications.
- The current governance of street space management is fragmented, leading to unclear enforcement bodies/standards in most cities. For example in Hangzhou, each district governs parking through different management measures and with uncoordinated management targets. Thus, cities need to form a **standardized and coordinated institutional system** with strong collaboration with DBS operators to enable an equitable DBS market.

5.4 Cycling Infrastructure Improvement

As vulnerable road users, cyclists travel with a higher risk of accident-related injury than drivers. Survey results show that 70 percent of people do not consider urban roads safe enough for cycling. The top three most dangerous factors for cyclists in the 12 cities are complicated intersections, lack of bike lanes, and conflict with e-tricycles for logistics use (Figure 5-4). Road environment risks appear to be great concerns and reflect the lack of safe cycling infrastructure in cities, which could be addressed by upgrading urban infrastructure and management for safe travel. The new e-bikes and e-scooter national standards were introduced in 2018 to improve safety from a vehicle standards perspective (Box 5-3).

Figure 5-4 | **What Are the Most Dangerous Aspects of Your Bike Trip? [Select up to 3]**



Note: n = 8,218.
Source: Survey results.

Although shifting from cars to bikes will increase exposure to the risks of motorized traffic, authorities may improve infrastructure safety as the number of cyclists increases (Wegman et al. 2012) and vice versa (Dill 2003). The *Guidelines on Urban Planning and Development* released in 2016 by the State Council emphasized the concept of "small blocks and narrow streets," which prioritized walking, cycling and public transit over car use and challenged the existing facilities. If bike share is introduced with a host of supportive measures, particularly dedicated parking areas, protected bike lanes, etc., service quality and safety will be considerably enhanced, and it's more likely that people will choose bikes for travel.

Among the 12 cities, 9 required **cycling facilities improvement** in the shared bikes regulations and the city's Transportation Plan or Non-motorized Transport Plan, especially increasing bike lane networks and parking facilities. Shenzhen planned to construct at least 1,000 kilometers of bike lanes across the city by the end of 2020 (Shenzhen Municipal Bureau of Transport 2018). Beijing, Shanghai, and Guangzhou released the *Street Design Guidelines,* addressing the right-of-way of cycling and the safety of vulnerable road users. Shanghai's street design manual prioritizes cycling over cars, as it indicates safer designs for cycling; for example, protected bike lanes, a dedicated signal phase for cyclists at intersections, and traffic-calming measures to manage vehicle speeds on local streets, etc.

New cycling infrastructure has been built across the country to showcase cities' cycling-friendly environment. For example, Xiamen and Beijing opened bike-only expressways in 2017 and 2019, to provide a faster and safer traveling experience (Figure 5-5). In 2019, Chengdu introduced a pioneering parking solution—an underground shared bikes parking facility next to a metro station (Figure 5-6), which can accommodate 224 bikes underground to avoid the obstruction hazard (Yan 2018).

Figure 5-5 | **Bike-Only Expressways Built in Xiamen (left) and Beijing (right)**

Source: China Economic Net 2019; Deng 2018.

Figure 5-6 | **Underground Parking for Shared Bikes in Chengdu**

Source: Hunan Intelligent Parking 2019; China Economic Net 2019.

Most Chinese cities have started to promote walking and cycling, and more cycling facilities have been built and improved. However, with rapidly growing numbers of DBS cyclists in cities, more convenient and safer infrastructure should be built to address travel demands.

- Although some cities address the significance of prioritizing cycling in the General/ Non-motorized Transport Plan and design standards, the **safety-oriented design should be included** in the plan/standards, to enable more dedicated cycling facilities; for example, dedicated cycling facilities, traffic-calming measures, safer crossings for cyclists at intersections, and so on.
- Dockless shared bikes have been playing a stronger role in the first/last-mile solution in Chinese cities. The good bike-and-ride experience requires **dedicated design and smart facilities around transit stations,** yet most cities have not integrated cycling facilities with public transportation. In 2015, Guangzhou released the *Design Standards for Accessible Metro Stations,* specifying standards on cycling facilities around stations to enhance the first/last-mile connection.
- **Awareness and targeted education on road safety** (e.g., wearing helmets, compliance, etc.) should still be improved in most cities, especially for vulnerable road users, to enable a safer and healthier cycling environment.

Box 5-3 | Shared E-bikes and E-scooters in China

Shared e-bikes and scooters are not encouraged in Chinese cities due to road safety and management concerns. Although the new national standards of Safety Technical Specifications for Electric Bicycles (MIIT 2018) enacted in April 2019, state that a qualified e-bike cannot surpass 25 km/hour, that speed would still increase the risk of injury in crashes involving cyclists and pedestrians. The development of shared e-bikes would require safer roads and pose greater danger for other vulnerable road users.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CHAPTER 6

CONCLUSIONS

This chapter highlights key findings about DBS impacts on Chinese cities and presents a package of policy implications. It also summarizes the strengths and limitations of the study. Finally, we suggest a series of future studies to push the boundaries of interdisciplinary research encompassing new and emerging shared mobility, social-economic impact assessments, and policies and urban management.

6.1 Findings and Highlights

Introducing DBS into cities has instigated controversy about its risks and benefits; this study investigates the impacts of DBS in 12 Chinese cities on travel behavior change, public health, emissions mitigation, and road safety.

Travel behavior change:

- Despite large geographical and socioeconomic differences, results show that DBS has a homogenous impact on travel behavior change among the 12 studied cities.
- The findings indicate that DBS increased connectivity to other modes, **54 percent** of respondents used DBS to connect to other modes, and **91 percent** of their linking trips were used to access public transport.
- Depending on the city, **17—45 percent** of total dockless bike-sharing kilometers traveled replaced motorized kilometers traveled (including private cars, taxis, ride-hailing, and motorcycles).

Health impact:

- Based on this research, health benefits from DBS cycling outweigh risks from exposure to polluted air while cycling, therefore cycling should be further encouraged. The net mortality avoided among 235 million Chinese dockless shared bike users would be **59,635** (95% CI 33,181–90,142) annually.
- For most Chinese cities with average $PM_{2.5}$ concentration within 50-60μg/m³, **one-hour of cycling per day could produce maximum health benefits.** Cycling more than 30 minutes per day at $PM_{2.5}$ levels above 160μg/m³ is not recommended.

Carbon mitigation impact:

- DBS could reduce total CO_2 by **4.8 million tonnes** annually, due to kilometers avoided from private motorized modes. However, emissions reduction is not as large as expected, because most of the replaced trips were short-distance (first/last mile) and were previously finished by walking and public transport.

Safety impact:

- Perceived safety was generally low among dockless shared bike users in the 12 cities. Only 7 percent of respondents reported feeling safe while cycling. The built-environment for cyclists is not improving fast enough to accommodate surging DBS usage.
- Neither empirical data nor academic or commercial studies in China have quantified the road safety risk difference between using DBS and using other types of bikes. Therefore, among total bike fatalities in China in 2018 (20,751), our analysis attributed **15,556** (95% CI 14,669–16,443) to DBS, more than half of the total, based on its significant share of total cycling mileage.

Furthermore, cities have improved DBS fleet management and cycling facilities to safeguard the cycling environment and actively promote cycling as a sustainable mobility solution. The regulatory response and its trends provide useful references for other cities that plan to adopt DBS systems.

Regulation and management implications:

- **Fleet size management.** Overall, cities evolved from a laissez-faire approach to a proactive regulation of fleet size by capping the DBS fleet number with stringent management measures. Yet cities still need to develop scientifically based methodologies to estimate the total DBS fleet and design incentive schemes for DBS operators to encourage DBS as a green and healthy transport mode.
- **Performance-based evaluation.** Setting up a KPI system to determine permit renewal/termination based on operators' performance not only allows the public sector to have a strong regulatory framework on fleet size management, but also offers a strong incentive for operators to provide quality service.
- **Regulated parking.** Cities should set up DBS parking design standards, creating clear rules on how curb space should be used, especially at critical locations like intersections, public transit stations, schools, and so on.
- **Standardized technologies.** To enable users to better follow rules, cities should encourage standardized technology applications for parking management, since they could enhance

efficiency and save the public sector workforce and operators expense and effort.

- **Dedicated cycling facilities and safety design.** DBS should be introduced with dedicated cycling infrastructures and with higher safety design standards to improve accessibility of cycling as a preferred sustainable transport mode, by upgrading the Comprehensive Transport Plan, Non-motorized Transport Plan, and Street Standards.
- **Road safety awareness and targeted education.** Road safety awareness and targeted education should focus on enabling a safer and healthier cycling environment.

6.2 Strengths and Limitations

Our study is the first of its kind to quantify the health, carbon, and safety impacts of DBS across a large span of Chinese cities. It provides a comprehensive review of how DBS changes citizens' travel behavior, and reviews several policies from 12 Chinese cities. This study fills gaps in existing literature on the health impact assessment (HIA) that focuses only on cycling in general instead of DBS as a specific subgroup. In addition, findings from our large-scale DBS survey also enrich and inform global studies and regulations. Based on these strengths, our study shares implications with different audiences:

- **Decision-makers** can refer to the quantitative impacts of DBS to guide their city's investment decisions or to adopt the recommendations to better manage DBS in fleet control, parking, and cycling facilities.
- **The general public** can refer to our recommendations and choose the appropriate daily cycling intensity to maximize health benefits.
- **Academic communities** can use results to enrich the existing studies worldwide and to publish comparative findings.

The study also has some limitations:

- **Survey design and data collection:** As survey data were collected online, the sample had a bias, featuring a larger number of younger and middle- and lower-income respondents. Also, survey questions were designed to understand the DBS finished short-distance trips, and understate the role of DBS in the mid- and long-distance trip chain.
- **Health impact assessment:** We adopted DRFs and took most assumptions directly from the existing literature in this study, which would not necessarily fit the actual local situations in Chinese cities. Some Chinese cities might have extremely high seasonal air pollution in winter. Despite low annual $PM_{2.5}$ concentration, most Chinese cities have extremely high air pollution in peak hours and along roadsides, where the exposed population (mainly daily commuters) is much larger than the population in off-peak hours. All these factors might sharply outweigh the benefits of cycling in an extremely nonlinear dose-response curve, but this scenario is not considered in this study. In addition, we did not consider the "net impact" of DBS within the entire transport system, which might lead to an overestimation of health benefits; for example, walking and its health benefits, which have been substituted by DBS could lead to fewer user benefits. All the above issues might produce inaccurate results.
- **Cycling fatality assessment:** The current DBS scan report didn't deep dive into the safety evaluation due to a lack of quality and longitudinal data in cities. To further improve the crash assessment (1) more DBS user activity data and city-specific biking mode share data (mode shares among private bikes, docked bike-sharing and dockless bike-sharing) need to be collected; (2) positive contributions from safer cycling infrastructures should be considered and quantified; and (3) influences of enlarged biking populations and presence on roads should be considered.
- **Policy review:** There are also some limitations in policy review and consequent implications. First, the policy review focus on regulation measures addressing the oversaturated market and street chaos caused by DBS does not cover a wider spectrum of DBS management areas from the enterprises' perspectives; for example, bike maintenance and DBS operations. As a few regulatory documents have not been disclosed/released to the public after completion of the final drafts, the policies under review might slightly underrepresent management measures undertaken in cities.

6.3 Future Studies

In future studies, we will aim to fill in the gaps as mentioned above. In addition, we also consider covering the following topics to push the frontier of bike-sharing studies in Chinese cities.

- **Impact monetization:** To support decision-making in a quantitative manner, we will monetize the costs and/or benefits of DBS, such as monetizing the health impact on the physical activity of cycling, carbon reduction, air pollutants exposure, and crash risk, as well as the impact on travel time (e.g., time saved), and on the economy and productivity. This economic valuation requires further studies on the localization of the value of a statistical life (VSL), social cost of carbon (SCC), and the social discount rate (SDR) in different Chinese regions. In addition, other costs or willingness-to-pay due to morbidity, loss of ability to work, and other such conditions will also be considered.
- **Morbidity study:** In addition to mortality (number of premature deaths) assessment, future studies will also consider the number of morbidities from different kinds of cycling-related outcomes. This is a challenging task due to multi-morbidities. In addition to headcounts of mortality and morbidity, we will also use the disability-adjusted life year (DALY) as a measure to assess the overall disease burden associated with cycling. According to WHO, *"One DALY can be thought of as one lost year of 'healthy' life. DALYs for a disease or health condition are calculated as the sum of the Years of Life Lost (YLL) due to premature mortality in the population and the Years Lost due to Disability (YLD) for people living with the health condition or its consequences"* (WHO n.d.). In doing so, mortality and morbidity are combined into a single, common metric.[16]
- **Other impacts and health outcomes breakdown:** Other health and socioeconomic-related impacts, such as noise avoided by replacing motorized transport with bikes, travel time saved, impacts on gender and income equity, education and hospital accessibility, and productivity changed, will also be assessed in future studies. We will involve sociologists and apply a mixed-methods approach (that combines qualitative with quantitative methods) in a fast consumer culture as found in most Chinese cities. Such "mixed-methods approach" could contribute particularly well to the development of gender, age, equity, and other socially sensitive strategies (Christensen 2019). Additionally, we will break down health impact assessment by specific categories of age, sex, and type of disease. These future studies require the availability and transparency of local data in cities, which must be carefully verified to reflect the true situation.
- **Selecting one or two cities for in-depth studies:** We are also considering choosing one or two cities with relatively good data availability to conduct further studies and address the limitations mentioned above. First, to yield more accurate survey results, we will consider investigating how DBS plays a role in the full trip chain. We will also use an off-line survey to tilt the age bias of the online survey. In the meantime, we will continuously track and review local policies and other forms of shared micro-mobility of selected cities. Pragmatic evaluation of delivery and process will produce important findings to direct policies and practices and shape policy recommendations and solutions for local cities.

APPENDIX A: QUESTIONNAIRE

[Prescreen question] Are you over the age of 12?
- ☐ Yes [continue to answer the survey]
- ☐ No [quit the survey]

[Prescreen question] Have you lived in this city at least six months?
- ☐ Yes [continue to answer the survey]
- ☐ No [quit the survey]

1. How long have you been registered as a dockless shared bike user?
- ☐ Never
- ☐ < 6 months
- ☐ 6–12 months
- ☐ > 1 year

2. How often have you used the dockless shared bike in the past six months?
- ☐ < 1 time a week
- ☐ 1–2 times a week
- ☐ 3–5 times a week
- ☐ 6–10 times a week
- ☐ > 10 times a week
- ☐ Not sure

3. What is the most common distance you typically travel per bike trip?
- ☐ < 1 km
- ☐ 1–2.9 km
- ☐ 3–4.9 km
- ☐ 5–9.9 km
- ☐ > 10 km
- ☐ Not sure

4. Minutes per bike trip?
- ☐ < 10 min
- ☐ 11–20 min
- ☐ 21–40 min
- ☐ 41–60 min
- ☐ > 60 min
- ☐ Not sure

5. What is your travel purpose (or destination) by dockless shared bikes? [Select up to 3]
- ☐ Connect to other transport modes (e.g., bus, metro, car)
- ☐ Commute to work
- ☐ Commute to school
- ☐ For leisure or entertainment (e.g., movies, restaurant)
- ☐ Grocery shopping
- ☐ Other shopping (e.g., department store, clothing)
- ☐ For fitness/health
- ☐ Personal business (e.g., hospital, bank)
- ☐ Business travel
- ☐ Travel to an educational place
- ☐ Taking kids to school
- ☐ Other (please specify) ________

6. Thinking about the trip you make most frequently with the dockless bike-sharing system, how did you make this trip before using dockless bikes? [Select up to 3]
- ☐ I wouldn't have made this trip
- ☐ Walking
- ☐ Bus
- ☐ Metro, tram, or light rail
- ☐ Taxi
- ☐ App-based on-demand taxi (e.g., ride-hailing, ride-sharing)
- ☐ Private car (as a driver)
- ☐ Private car (as a passenger)
- ☐ Personal bike
- ☐ Public bike (docked bike-sharing)
- ☐ E-bike
- ☐ Motorcycle
- ☐ Other (please specify) ________

7. What other modes (excluding walking) do you use to combine with a dockless shared bike trip (e.g., pick up a bike at a metro station to complete your journey)?
- ☐ Bus
- ☐ Metro, tram, or light rail
- ☐ Taxi
- ☐ App-based on-demand taxi (e.g., ride-hailing/ride-sharing)
- ☐ Private car (as a driver)
- ☐ Private car (as a passenger, e.g., carpool with friends)
- ☐ Do not connect to any other transportation.
- ☐ Other (please specify)

8. What are the reasons that you like using the dockless shared bike? [Select up to 3]

- ☐ Better for environment
- ☐ Exercise/health
- ☐ Safe
- ☐ Cheap
- ☐ Easy to find or park
- ☐ Time-saving (e.g., avoid congestion and parking)
- ☐ Easy to combine with other transport (e.g., bus, metro, car)
- ☐ Avoid unpleasant experience in public transport (e.g., no seat, too crowded, sexual harassment)
- ☐ No worry of bike theft, storage, and maintenance
- ☐ Good alternative to public transport when this is not easily available (e.g., midnight, remote places)
- ☐ Trendy
- ☐ Other (please specify) ________

9. How do you think dockless bike-sharing changes your life quality (in terms of the following aspects)?
(From 1 to 5, 1 = Very bad impact; 3 = Neutral/No impact; 5 = Very good impact)

	1	2	3	4	5
Physical health	☐	☐	☐	☐	☐
Mental health (happy)	☐	☐	☐	☐	☐
Confidence	☐	☐	☐	☐	☐

10. What vehicle do you own and use most? [Select up to 3]

- ☐ No car available in my family
- ☐ E-bike
- ☐ Motorcycle
- ☐ Electric car
- ☐ Small or mid-size car (<1.6L)
- ☐ Full-size car (1.6–2.4L)
- ☐ SUV (2.4–4.0L)
- ☐ Minivan (>4.0L)
- ☐ Other (please specify) ________

11. Annual kilometers traveled by your own vehicle?

- ☐ < 5,000 km
- ☐ 5,001–10,000 km
- ☐ 10,001–15,000 km
- ☐ 15,001–20,000 km
- ☐ 20,001–25,000 km
- ☐ 25,001–30,000 km
- ☐ 30,001–40,000 km
- ☐ 40,001–50,000 km
- ☐ Not sure

12. What are the reasons that you don't like using the dockless shared bike? [Select up to 3]

- ☐ APP is not user-friendly
- ☐ Difficult to find bikes
- ☐ Parking is not convenient
- ☐ High cost of fare and deposit
- ☐ Feel insecure about getting deposit back
- ☐ Poor or limited biking facilities
- ☐ Unsafe and complex biking environment/dangerous road traffic
- ☐ Poor bike quality and maintenance
- ☐ Dirty bike or illegal ads on bikes
- ☐ Worry about personal info being exposed or abused
- ☐ Negative impact on public space and urban beautification
- ☐ Other (please specify) ________

13. What problems do you think dockless shared bikes pose to your city?
(From 1 to 5, 1 = No impact; 3 = Average impact; 5 = Extremely bad impact)

	1	2	3	4	5
Block sidewalks	☐	☐	☐	☐	☐
Block carriageways	☐	☐	☐	☐	☐
Block bus stations	☐	☐	☐	☐	☐
Block metro stations	☐	☐	☐	☐	☐
Disorder urban streetscape	☐	☐	☐	☐	☐
Block vehicle parking space	☐	☐	☐	☐	☐

14. What do you think of the air pollution situation in your city?

- ☐ Severe air pollution
- ☐ Bad air quality observed but acceptable
- ☐ No air pollution
- ☐ Not sure

15. How do you think air pollution affects your health during cycling? (From 1 to 5, 1 = No impact; 3 = Average impact; 5 = Extremely bad impact)

- ☐ 1 No impact
- ☐ 2 Some impact
- ☐ 3 Average impact
- ☐ 4 Very negative impact
- ☐ 5 Extremely negative impact
- ☐ Not sure

16. Are you still willing to ride if there is air pollution?

- ☐ Yes, but will ride less frequently or less distance
- ☐ Yes, will ride anyway
- ☐ No

17. Do you feel safe when cycling?
(From 1 to 5, 1 = Not safe at all; 5 = Completely safe)

- ☐ 1 Not safe at all
- ☐ 2 Not safe
- ☐ 3 Neutral
- ☐ 4 Safe
- ☐ 5 Completely safe
- ☐ Not sure

18. What are the most dangerous aspects of your bike trip?
[Select up to 3]

- ☐ Complicated intersections
- ☐ Lack of bike lanes
- ☐ Bike lanes encroached by cars
- ☐ Conflict with bus at bus stop
- ☐ Conflict with e-tricycles for logistics use
- ☐ Conflict with e-bikes
- ☐ Conflict with trucks
- ☐ Conflict with cars
- ☐ Conflict with motorcycles
- ☐ Conflict with other cyclists and pedestrians
- ☐ Other (please specify) ________

19. Gender

- ☐ Female
- ☐ Male

20. What is your personal monthly income (in ¥)?

- ☐ No income
- ☐ < 2,000
- ☐ 2,001–4,000
- ☐ 4,001–6,000
- ☐ 6,001–8,000
- ☐ 8,001–10,000
- ☐ 10,001–20,000
- ☐ 20,001–50,000
- ☐ 50,001–100,000
- ☐ > 100,000

21. Age

- ☐ 12–18
- ☐ 19–25
- ☐ 26–35
- ☐ 36–45
- ☐ 46–55
- ☐ 56–65
- ☐ 66–75
- ☐ > 75

APPENDIX B: SHARED BIKES REGULATIONS

	Guiding opinions
National-level	Guiding Opinions of the State Council on Giving Priority to Public Transportation in Urban Development Guiding Opinions on Encouraging and Regulating the Development of Bike-Sharing System (2017)
Beijing	Guiding Opinions of Beijing on Encouraging and Regulating the Development of Bike-Sharing System Technical and Service Specification of Bike-Sharing Systems in Beijing
Shanghai	Guiding Opinions of Shanghai on Encouraging and Regulating the Development of Bike-Sharing System
Guangzhou	Guiding Opinions of Guangzhou on Encouraging and Regulating the Development of Bike-Sharing System
Shenzhen	Opinions on Encouraging the Development of Shared Bikes Service Specifications for Bike Sharing in Shenzhen Regulations on the development of Bike-Sharing in Shenzhen (Draft) Implementation Plan of Developing Cycling in Shenzhen
Wuhan	Guiding Opinions of Wuhan on Encouraging and Regulating the Development of Bike-Sharing System

Parking guides	Management and assessment	Vehicle and other technical guides	Street design guide
Technical Guidelines for Bike Parking (Beijing, 2017) Guidelines of Applying GPS- and Geofencing-based technologies on Bike-Sharing Management (2017)	Regulations on Non-motorized Vehicle Management in Beijing (2018)		Urban Design Guidelines for Beijing Street Regeneration and Governance
Technical Guidelines for Non-motorized Vehicle Parking (Trial)	Management Measures of Non-motorized Vehicle in Shanghai (2013) Management Measures Bike Sharing in Shanghai (Draft) Assessment Measures for Service Level of Bike-Sharing Operators in Shanghai	Management Standards of Bike-Sharing (I): Pedal Bikes Management Standards of Bike-Sharing (II): Electric Bikes Service Specification for Bike-Sharing System (Shanghai)	Shanghai Street Design Guidelines
Technical Guidelines for Bike Parking in the Central Districts of Guangzhou			Guangzhou Complete Street Design Manual Design Standards for Accessible Railway Stations
Guidelines for Bike Parking (On sidewalk space) in Shenzhen	Implementation Plan for Regulating Shared Bikes (Shenzhen) Interim Measures for Regulating Shared Bike Parking in Shenzhen (Draft) Implementation Guidelines of Administrative Punishment on Breaches of Bike-Sharing Implementation Plan for Bike-Sharing Operators Credit Management KPIs for Service Level of Bike-Sharing Operators Assessment in Shenzhen	Technical Requirements of Shared Bikes in Shenzhen	
	Non-motorized Vehicles Management Measures in Wuhan (Trial-Draft) Assessment Measures for Service Level of Bike-Sharing Operators in Wuhan		

	Guiding opinions	Parking guides	Management and assessment
Hangzhou	Guiding Opinions of Hangzhou on Encouraging and Regulating the Development of Bike Sharing (Trial)	Technical Guidelines for Bike Parking in the Central Districts of Hangzhou	Assessment Measures for Service Level of Bike-Sharing Operators in Hangzhou
Xiamen	Guiding Opinions on Encouraging and Regulating the Development of Bike-Sharing System (Xiamen)	Technical Guidelines for Bike Parking in Xiamen Guidelines for Bike Parking in Xiamen (Trial) Planning for Non-motorized Vehicle Parking	Implementation Plan for KPI-based Fleet Size Adjustment in Xiamen, 2019
Xi'an	Guiding Opinions of Xi'an on Encouraging and Regulating the Development of Bike-Sharing System		Management Standard and Measures of Shared Bike Parking in Xi'an
Chengdu	Opinions on Encouraging and Regulating the Development of Bike Sharing in Chengdu (Trial) Service Specifications for Bike Sharing Operation in Chengdu (Trial)	Technical Guidelines for Non-motorized Vehicles Parking in the Central Districts of Chengdu (Interim)	Assessment Measures for Service Level of Bike-Sharing Operators in Chengdu Measures for Regulating Shared Bike Parking in Chengdu (Trial) Assessment Measures for Parking Performances of Shared Bikes
Jinan	Guiding Opinions of Jinan on Encouraging and Regulating the Development of Bike-Sharing System (Trial-Draft)	Technical Guidelines for Shared Bikes Parking in the Central Districts of Jinan	
Nanjing	Guiding Opinions of Nanjing on Encouraging and Regulating the Development of Bike-Sharing System (Trial)		KPI System of Assessing Service Quality of Bike-Sharing Operators in Nanjing Regulations on Fleet Deployment of Shared Bikes in Nanjing (Draft)
Lanzhou	Guiding Opinions of Lanzhou on Encouraging and Regulating the Development of Bike-Sharing System		

Vehicle and other technical guides	Street design guide
Ten Don’ts of Using Shared Bikes in Jinan Regulations on Market Entry for Bike-Sharing Operators	

Notes: A couple of regulatory documents are unavailable on government websites, including *Technical Guidelines for Shared Bikes Parking in the Central Districts of Jinan, Regulations on Market Entry for Bike-Sharing Operators*, and *Technical Guidelines for Bike Parking in the Central Districts of Hangzhou*.

Sources: National Level: The State Council 2012; Ministry of Transport of China et al. 2017; Beijing Municipal Bureau of Economy and Information Technology 2017.
Beijing: Beijing Municipal Commission of Transport et al. 2017; Beijing Municipal Commission of Transport 2017; Beijing Traffic Management Bureau 2018; Beijing Municipal Commission of Planning and Natural Resources and Beijing Municipal Institute of City Planning and Design 2017.
Shanghai: Shanghai Municipal People’s Government 2017a, 2017b; Shanghai Municipal Bureau of Planning and Land Resource Management 2016; Shanghai Bicycle Association and Tianjin Bicycle and Electric Bicycle Association 2017a; X. Xu 2017; Shanghai Bicycle Association and Tianjin Bicycle and Electric Bicycle Association 2017b; Shanghai Municipal Transportation Commission 2019a.
Guangzhou: Guangzhou Municipal Commission of Transport et al. 2018; Guangzhou Municipal Transportation Bureau 2017; Guangzhou Housing and Urban-Rural Construction Commission 2017; Guangzhou Municipal Bureau of Housing and Urban-Rural Construction 2015.
Shenzhen: Shenzhen Municipal Commission of Transport et al. 2017b; Shenzhen Municipal Bureau of Transport 2019b; Shenzhen Municipal Commission of Transport et al. 2017a; Shenzhen Municipal Bureau of Transport 2017a; Justice Bureau of Shenzhen Municipality 2019; Shenzhen Municipal Bureau of Transport 2017b, 2019a; Shenzhen Municipal People’s Government 2018.
Wuhan: Wuhan Municipal Bureau of Transport 2017; Wuhan Municipal Office of Justice 2018; Wuhan Municipal Commission of Transport 2018.
Hangzhou: Hangzhou Municipal Bureau of Transport 2017; Redsh 2017; Zhejiang Transportation Bureau 2018; Hangzhou Jixiao Administration Committee 2018.
Xiamen: Xiamen City Management Administrative Enforcement Bureau et al. 2017; Xiamen City Management Administrative Enforcement Bureau 2019a; *People’s Daily* 2017; Xiamen City Management Administrative Enforcement Bureau 2019b.
Xi’an: Wang 2017; Xi’an Municipal Bureau of City Management 2017.
Chengdu: Chengdu Municipal Bureau of Transport 2017; Chengdu Municipal Bureau of Public Security et al. 2018; Chengdu Municipal Bureau of City Management 2012; Chengdu Municipal Commission of Transport et al 2018; Chengdu Municipal Commission of City Management 2018.
Jinan: Jinan Municipal Bureau of Transport 2017; Hu and Wang 2017; Yin and Cui 2018; Zhang 2017.
Nanjing : Nanjing Municipal Bureau of Transport 2017; Nanjing Municipal Bureau of Transport et al. 2018; Nanjing Municipal Bureau of Transport 2019;
Lanzhou: Lanzhou Municipal Government 2018.

ENDNOTES

1. JHU coronavirus center 2020. https://coronavirus.jhu.edu/map.html.

2. Jie Gao. *Xinhua News*. 2020. http://www.xinhuanet.com/2020-03/12/c_1125702747.htm.

3. Equivalent to the carbon sequestered by up to 6.8 million acres of US forests in one year (https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator).

4. *E-scooters* in this study refers to a stand-up scooter powered by electricity, which is classified as micro-mobility.

5. China's national DBS management measure stipulates that DBS users should be older than 12 years.

6. Similar as the "single-case assessment" mentioned in HEAT (Kahlmeier et al. 2017).

7. Relative risk is a ratio of the probability of an event occurring in the exposed group versus the probability of the event occurring in the nonexposed group. Relative Risk = (Probability of event in exposed group) / (Probability of event in nonexposed group) (Andrade 2015).

8. The metabolic equivalent of task (MET) is the objective measure of the ratio of the rate at which a person expends energy, relative to the mass of that person, while performing some specific physical activity compared to a reference. One MET equals the resting metabolic rate of approximately 3.5 ml 0_2≅kg-1≅min-1, or, 1 kcal≅kg-1≅hr-1 (Physical Activities Center for Public Health: http://www.parcph.org/glossaryofterms.aspx).

9. We do not show the detailed methods in this report. The detailed description of the methods are in WHO 2014a; Kahlmeier et al. 2017; Tainio et al. 2016.

10. PAF is defined as the reduction in average disease risk by eliminating the exposure(s) of interest from the population, while the other risk factors in the population remain unchanged (Wang et al. 2018).

11. Mortality data can be obtained from either (1) the pdf report from the "World Population Prospects 2019," or (2) the Excel sheet ("Crude Death Rate") from https://population.un.org/wpp/Download/Standard/Mortality/.

12. The original links to the data are http://apps.who.int/gho/data/node.imr, and https://apps.who.int/gho/data/view.main.1360.

13. IHME's online database of GBD: http://ghdx.healthdata.org/gbd-2017; the current GDB 2017 is the most updated data online. This database is useful for checking mortality data for the specific health outcome, as well as the cause-specific mortality.

14. IHME's online database of visualized GBD data: https://vizhub.healthdata.org/gbd-compare/.

15. See Kelly et al.'s 2014 study, Table-2 for more information.

16. The disability-adjusted life year (DALY) is a measure of overall disease burden. One DALY can be thought of as one lost year of "healthy" life. The sum of these DALYs across the population, or the burden of disease, can be thought of as a measurement of the gap between current health status and an ideal health situation where the entire population lives to an advanced age, free of disease and disability (WHO Health Statistics and Information Systems: https://www.who.int/healthinfo/global_burden_disease/metrics_daly/en/).

GLOSSARY

All-cause mortality (ACM) All-cause mortality is the death rate from all causes of death for a population in a given time period.

Comparative risk assessment (CRA) Comparative risk assessment is defined as the systematic evaluation of the changes in population health that result from modifying the population distribution of exposure to a risk factor or a group of risk factors (WHO 2000).

Disability-adjusted life year (DALY) The disability-adjusted life year is a measure of overall disease burden. One DALY can be thought of as one lost year of "healthy" life. The sum of these DALYs across the population, or the burden of disease, can be thought of as a measurement of the gap between current health status and an ideal health situation where the entire population lives to an advanced age, free of disease and disability.

Dockless bike-sharing (DBS) system DBS is a new form of cycling scheme offering apps where riders can locate bicycles, unlock them, and leave them wherever their ride ends.

Dose-response functions (DRFs) Dose-response functions, or exposure-response functions, quantitatively describe how much a specified health effect changes when exposure to the specified agent changes by a given amount (IEHIAS n.d.).

Health impact assessment (HIA) Health impact assessment is a combination of procedures, methods, and tools used to evaluate the potential health effects of a policy, program, or project. Using qualitative, quantitative, and participatory techniques, HIA aims to produce recommendations that will help decision-makers and other stakeholders make choices about alternatives and improvements to prevent disease/injury and to actively promote health (WHO n.d.)

Metabolic equivalent of task (MET) The metabolic equivalent of task is the objective measure of the ratio of the rate at which a person expends energy, relative to the mass of that person, while performing some specific physical activity compared to a reference. One MET equals the resting metabolic rate of approximately 3.5 ml O_2≅kg−1≅min−1, or, 1 kcal≅kg−1≅hr−1 (Physical Activities Center for Public Health n.d.).

Particulate matter ($PM_{2.5}$) $PM_{2.5}$ describes fine inhalable particles, with diameters that are generally 2.5 micrometers and smaller (EPA n.d.).

Population-attributable fraction (PAF) PAF is defined as the reduction in average disease risk by eliminating the exposure(s) of interest from the population, while the other risk factors in the population remain unchanged (Wang et al. 2018).

Public bike (docked) systems A public bicycle scheme allows users to hire bikes on a short-term basis, and the systems only allow people to borrow and return bikes from one dock to another. Most public bike systems in China are operated by local municipal governments and offer an affordable price or are free.

Relative risk (RR) Relative risk is a ratio of the probability of an event occurring in the exposed group versus the probability of the event occurring in the nonexposed group. Relative Risk = (Probability of event in exposed group) / (Probability of event in nonexposed group) (Andrade 2015).

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