



BUS RAPID TRANSIT IN CHINA: A COMPARISON OF DESIGN FEATURES WITH INTERNATIONAL SYSTEMS

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EXECUTIVE SUMMARY

Globally, bus rapid transit (BRT) has proved itself to be a high-capacity public transport mode that can be implemented in short time frames and at relatively low capital cost. Its benefits—reducing greenhouse gas and local air pollutant emissions, improving traffic safety, and reducing passenger travel times—are well documented.

BRT can play an important role in China, contributing to sustainability in the urban transport sector and beyond. Recognizing its importance, China has set a national goal of implementing 5,000 kilometers of BRT by 2020 (MOT 2013a). As of 2015, China had implemented 2,991 kilometers of BRT, according to the China Academy of Transportation Sciences. To reach its goal, it will therefore need to build more than 2,000 kilometers of BRT corridors in the next three years.

BRT in China is still considered a second-class service option, after urban metros and private vehicles (Deng et al. 2013; Zeng 2013). Changing people’s perception and demonstrating that BRT represents a viable public transport mode will require improving the design and performance of BRT in China so that both meet international standards.

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Research Approach

This working paper benchmarks China's BRT systems against systems in other countries based on the indicators used by the Institute for Transportation and Development Policy (ITDP). It assesses 30 of the 38 ITDP indicators, based on their relevance to design characteristics. The study uses analysis of variance to compare the differences between mean Chinese and international BRT, based on 99 data points representing 59 cities (18 in China) and 21 countries.

Key Findings

The paper identifies 11 indicators for which Chinese BRT systems exhibit statistically significant lower scores than their international counterparts (Figure ES-1). These indicators include the following:

- **Intersection treatment:** China can improve the way intersections function by giving more priority to BRT buses and reducing bus travel times by employing functional transit signal priority systems and prohibiting all or most turns across the BRT busway.
- **Express or limited-stop services and passing lanes:** Increasing the number of BRT systems with express or limited-stop service would enable faster service and increase passenger capacity by reducing cycle times and reducing lines at stations. Passing lanes at stations are needed to provide such services. Addition of these features where appropriate needs to reflect the urban context, including required capacity, availability of space, and travel patterns.
- **Minimum station setback lengths:** Providing minimum station setback lengths can expedite BRT services by enabling buses to stop for passenger boarding and disembarkation, so that buses are not blocked by downstream buses at the intersection while waiting for traffic lights to turn green.
- **High-quality BRT in multiple high-demand corridors:** To fully realize the potential of BRT systems, where appropriate, systems should create multicorridor and/or multimodal networks. The networks should serve high-demand corridors in cities by implementing median-aligned, dedicated busways, especially in areas with the greatest roadway congestion. For relevant cities (such as Guangzhou), allocating scarce corridor land resources more efficiently by giving higher priority to public transport can help achieve high-quality services.

- **Distance between stations:** BRT systems can balance coverage and speed by spacing stations at an optimal distance. Many countries space stations 300 to 800 meters apart, which results in reasonable walking distances and rapid operation of the bus system (ITDP 2014a).

As part of best practices, Chinese BRT systems also need to reduce emissions and ensure that all passengers, including passengers with special needs, can access and use stations and buses.

1. INTRODUCTION

China's urbanization rate reached 57 percent by the end of 2016 (World Bank 2017); it is forecasted to reach 70 percent (almost 1 billion people) by 2030 (UNDP China 2013). The number of registered motor vehicles reached 154 million by the end of 2014 and is projected to exceed 200 million by 2020 (EU SME Centre 2015).

If no decisive action is taken, these trends will result in a 123 percent growth in vehicle kilometers traveled between 2010 and 2030 (IEA 2016), with large negative impacts on congestion, air pollution, energy consumption, and traffic fatalities. The challenge for Chinese policymakers is therefore to serve growing demand for mobility through a mix of public transit modes, which can address these urgent challenges and help mitigate climate change.

Chinese policymakers have recognized the importance of investing in public transport to shift away from road expansion plans, which constituted the core of transport planning in the 1990s. In 2011, the Ministry of Transport (MOT) launched the National Transit Metropolis Demonstration Project. One of its main aims was to increase the share of public transport to more than 50 percent in selected cities (Velásquez et al. 2016). By 2016, 37 Chinese cities had been selected to participate; more than 50 additional cities are projected to join by 2020 (MOT 2016).

As a result of leadership from the central government, 26 cities had constructed metros by January 2016, and the government has approved another 39 cities for urban rail transit planning (Goh 2016). Buses also play a very important part of mobility in Chinese cities, and some of these bus systems have a higher mode share than metros. For example, Beijing's metro, which is over 500 kilometers in length, carries 10 percent of commuting trips, compared with 25 percent carried by buses (Yang et al. 2017). In Chengdu, the development of metro lines is still in its nascent stage; residents there rely largely on the city's extensive bus networks, which account for almost 30 percent of all travel (Zhao et al. 2014).

Figure ES-1 | **International and Chinese Bus Rapid Transit: Findings from Analysis of Variance**

CATEGORY	INDICATOR	PERIOD 2013-14
BRT basics	Off-board fare collection	25.7
	Platform-level boarding	13.4
	Busway alignment	0
	Dedicated right-of-way	-1.3
	Intersection treatments	-65
Service planning	Control center	20.2
	Hours of operation	10
	Multiple routes	8.3
	Located in top 10 corridors	-13.4
	Multicorridor network	-21.1
	Express, limited, and local services	-24.8
	Demand profile	-54.6
Infrastructure	Pavement quality	24.1
	Center stations	16.5
	Minimizing bus emissions	-29.3
	Passing lanes at stations	-31.4
	Stations set back from intersections	-54.1
Station design and station-bus interface	Sliding doors in BRT stations	41.8
	Number of doors on bus	14.1
	Safe and comfortable stations	10.6
	Docking bays and substops	-7.2
	Distances between stations	-27.7
Communications and marketing	Passenger information	18.2
	Branding	9.1
Integration and access	Bicycle lanes	24.5
	Integration with other public transport	13.1
	Bicycle-sharing integration	1.7
	Secure bicycle parking	-7.1
	Pedestrian access	-35.5
	Universal access	-70.6

Statistically significant difference

■ Yes
 ■ No

Notes: Sample size: 99 data points (23 in China and 76 in other countries). There is a 95 percent likelihood that these differences are not due to random chance.

Source: Based on data from ITDP (2014c).

The Importance of Bus Rapid Transit

China seems to be on the right track regarding bus rapid transit, or BRT (defined in Box 1). It seeks to implement 5,000 kilometers by 2020 (MOT 2013a). As of 2015, China had built 2,991 kilometers of BRT, according to the China Academy of Transportation Sciences (CATS).¹ To reach its goal, it will therefore need to build more than 2,000 kilometers of BRT corridors in the next three years. The results and recommendations presented in this paper could help policymakers take a proactive, rather than reactive, approach to implementing them.

At the global scale, BRT has already proved its capacity to transport large numbers of passengers and to be implementable in short time frames at a relatively low capital cost. In addition to providing efficient transportation to millions of people, BRT reduces greenhouse gas emission, improves air quality, and reduces the number of traffic fatalities (Carrigan et al. 2013; Paget-Seekins and Muñoz 2016).

In keeping with the national goal (MOT 2013a), BRT can play an important role in urban transport in China, complementing metro systems in large urban areas or creating backbone mass transit networks in smaller cities. It can be an effective way to deal with the ongoing challenges of traffic congestion, environmental impacts, safety, and loss of productivity.

Box 1 | What Is Bus Rapid Transit?

Internationally, the criteria for a system to be called bus rapid transit (BRT) continue to be debated. BRTData, a global database established by EMBARQ/WRI Cities and the BRT Centre of Excellence (among others), defines *BRT* as a bus system that "(i) operates with wheels on road surface and has (ii) high operational speed, (iii) good frequency, and (iv) low headway, while including a unique (v) marketing identity" (BRT Centre of Excellence et al. 2017).

Levinson et al. (2003, 1), in one of the most cited definitions in the literature, describe BRT as, a "flexible, rubber-tired form of rapid transit that combines stations, vehicles, services, running ways and information technologies into an integrated system with a strong identity." Wright and Hook (2007, 12) chart a spectrum of tier-based public transport, defining a "full BRT" as a bus system that has the following characteristics: "metro-quality service; integrated network of routes and corridors; closed, high-quality stations; pre-board fare collection/verification; frequent and rapid service;

modern, clean vehicles; marketing identity; superior customer service." Only a few cities in the world achieve "full BRT" status, and not all cities need a "full" or "ideal" BRT system.

The draft version of the *Bus Rapid Transit System Planning and Design Guide*, cowritten by many transport institutions in China (including the China Academy of Transportation Sciences), defines *BRT* as "a rapid public transport mode that

- has large-capacity and high-performance public bus and trolleybus running along accommodation lanes and dedicated platforms;
- [sells] tickets outside a station and [has level passenger boarding]; and
- is controlled by the intelligent dispatching system, the right-of-way signal system, and the passenger information service system" (MOT 20xx, 2).

In addition to these features, the *Annual Report on the Development of the BRT Systems in Chinese Cities 2015* (CATS 2016) states that a BRT system must also include a unique vehicle design that incorporates large doors for easy access and user-friendliness, and uses clean energy.

This paper uses the broader term *bus priority systems* to denote BRT as well as other bus systems that have some type of priority over other vehicles by deploying infrastructure or operational improvements, such as fully or partially segregated lanes.

While the precise BRT definition is contested, experts agree that BRT can accommodate large capacity and high speed and be implemented in a short time frame with relatively low construction costs, as shown Tables B1.1 and B1.2.

TABLE B1.1 | CAPACITY AND SPEED OF SELECTED MODES OF PUBLIC TRANSPORT

TRANSIT MODE	CAPACITY (PASSENGERS PER HOUR PER DIRECTION)	COMMERCIAL SPEED (KM/HR)
Standard bus	3,180–6,373	10–30
Bus rapid transit	Up to 55,710	18–40+
Light rail transit	Up to 30,760	18–40
Heavy rail system	52,500–89,950	20–60

Source: Adapted from Carrigan et al. (2013).

TABLE B1.2 | CAPITAL COSTS OF BRT AND RAIL SYSTEMS (MILLIONS OF US DOLLARS)

TRANSIT MODE	RANGE	MEDIAN
Bus rapid transit	3.5–567	36.1
Rail	117–7,000	575.1

Source: Carrigan et al. 2013.

Purpose, Scope, and Structure of This Paper

China has made progress implementing BRT systems (Deng et al. 2013; Zeng 2013). But there is a great opportunity for many Chinese systems to achieve the capacities and speeds observed among the finest BRT systems elsewhere in the world. To be able to meet the growing travel needs of its people, China will require a combination of high-quality public transit modes—including BRT. As the recent white paper on China’s transport for the *13th Five-Year Plan* period (2016–20) states, China must set higher standards for the transport development to “realize the Chinese Dream of the great rejuvenation of the Chinese nation” (State Council Information Office 2016). In this spirit, this paper benchmarks BRT systems in China against international standards in order to identify areas that need improvement.

The performance of transit systems depends on many variables, including design features, the urban context, land use issues, funding and financing policies, institutional arrangements and capacity, and many others. In order to improve the performance of Chinese systems, this paper starts with the design variable. It identifies core design elements that could enhance the performance of BRT systems so that they become a high-quality component of advanced and integrated public transportation systems in China. There is a wide range of Chinese BRT systems within the country, and different eras of Chinese BRT are already compared in the literature (e.g., Fjellstrom 2010). In this working paper, the analysis is done by comparing design characteristics of BRT in China and the rest of the world.

The paper focuses on design elements because the effect of improved design on performance is well documented in the literature (e.g., Carrigan et al. 2013; Herrera et al. 2016; Larraín et al. 2016; Lindau et al. 2013), and, once implemented, many design features (including dedicated lanes and the distance between stations) are difficult to modify without incurring extensive costs. Given the substantial cost of retrofitting existing systems, the findings and discussions presented herein are most useful when cities are planning new corridors or major upgrades and extensions of existing systems.

Future research is required to explore other variables that affect BRT performance in China. The scope of the paper excludes comparing and benchmarking potential costs of implementing BRT design elements. The research is limited to

BRT; it does not provide recommendations for other levels of bus priority, which may be needed in some urban corridors.

This paper is not an exhaustive exposition but rather an invitation for dialogue on BRT in China. It is particularly beneficial for Chinese BRT engineers, planners, and decision makers during the planning and operational stages. The paper is also intended for a general international audience interested in the design and development of BRT systems in China, as its methodology and lessons have potential for replication in other world cities.

2. OVERVIEW OF BRT SYSTEMS IN CHINA

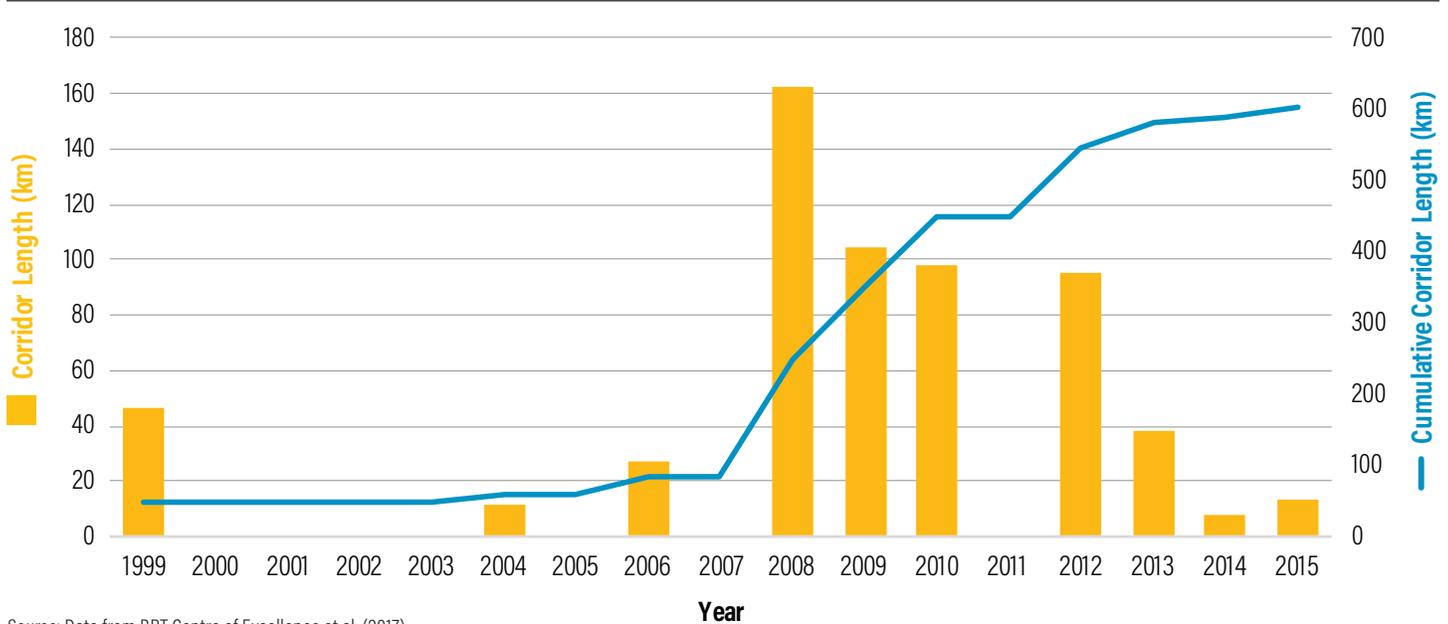
The Rapid Pace of BRT Development in China

In the past decade, China has added BRT corridors and other bus priority systems at a faster pace than any other country in the world and is now second only to Brazil in total service lane-kilometers (BRT Centre of Excellence et al. 2017; Cervero 2013). Based on the Global BRT Data, as of 2016 Chinese BRT and other bus priority systems have a ridership of approximately 4.4 million passengers per weekday in 20 cities across the country (BRT Centre of Excellence et al. 2017). The growth of BRT and other bus priority systems in China over the past two decades can be seen in Figure 1.

In 1999, less than two decades ago, the first proto-BRT, or enhanced bus service, was built in Kunming (Fjellstrom 2010). In 2004, China’s Ministry of Construction (MOC), now known as the Ministry of Housing and Urban-Rural Development (MOHURD), specifically recommended that BRT be made a priority for urban mass transit development (MOC 2004), as a practical and affordable strategy to address traffic congestion problems.

The recommendation from the MOC accelerated the development of BRT systems in China. China’s first BRT line was opened in Beijing in December 2004, and since then implementation of BRT has spread across the nation. The Guangzhou BRT system, which opened in February 2010, captured a peak passenger flow of 26,900 passengers per hour per direction—comparable to the highest-demand metro lines in mainland China. With a ridership of 800,000 passenger-trips per day (not including transfers), Guangzhou’s BRT in 2010 carried more daily passengers than any of the five metro lines in the city (Fjellstrom 2010). It is important to highlight that comparing BRT to heavy rail is not to disregard the countless merits of metros but to attest to the potential of BRT systems (see Box 1 for the ranges of BRT speed and capacity).

Figure 1 | Corridor Length of Bus Rapid Transit and Other Bus Priority Systems in China, 1999–2015



Source: Data from BRT Centre of Excellence et al. (2017).

In addition to BRT systems in several first-tier megacities such as Guangzhou, BRT is also pertinent for medium-sized and small Chinese cities with populations of fewer than 5 million people. The BRT corridor in the medium-sized city of Yichang, for example, earned a Gold standard² rating in 2015 based on the *BRT Standard* evaluation by the Institute for Transportation and Development Policy (ITDP). Yichang’s BRT also generated further interest in transit-oriented development in midsized cities in China (ITDP 2015). Many other BRT systems in China serve as an integral public transit mode. For instance, BRT ridership in cities, such as Changzhou, Xiamen, Zhengzhou, and Zaozhuang, accounted for more than 14 percent of the total public transport passengers (Zhang et al. 2013).

While many BRT systems in China were initially concentrated in first-tier cities in the eastern part of the country, many BRT systems were later constructed in cities in less-developed western China, such as Urumqi in 2011, Yinchuan in 2012, and Lanzhou in 2013 (Carrigan et al. 2013). Similar to other infrastructure projects in China, BRT systems in Chinese cities are often constructed with great momentum. For instance, the 40-kilometer Urumqi BRT system with four corridors took a mere three years to complete, while Changzhou’s municipal government finished the construction of the 30-kilometer Line 1 corridor in about a year, and Lianyungang’s city government built its 34-kilometer first corridor in eight months (Carrigan et al. 2013; CATS 2016; Urumqi Government 2013).

This fast-paced development is partly the result of Chinese municipal governments’ not needing approval from the central government to build a BRT system (unlike building a heavy-rail metro). Chinese mayors, compared to international standards, have more discretion in transport planning decisions, and, as a result, they are more likely to have firm leadership and required funds to build BRT projects (Deng et al. 2013).

Various policies from the central government also have helped maintain the momentum of BRT implementation over the years. In 2012, policy directives by the State Council issued in the Guidelines on Urban Public Transport Priority Development advocated for BRT as an important component for China’s surface public transport system (State Council Information Office 2012). The National Transit Metropolis Demonstration Project, first established in 2011 by the MOT, recently added four incentive policies for providing funding for selected “demonstration cities.” One of the incentive policies directly supports the deployment and application of a BRT intelligent information system (MOT 2013b). The *13th Five-Year Plan on National Economic and Social Development (2016–20)*, arguably one of the most important policy documents in China, also recommends the development of diversified BRT systems (People’s Republic of China 2016).

With rapid implementation, BRT had been adopted by 24 Chinese cities by the end of 2015, according to the official annual BRT report (CATS 2016). Based on the same

annual BRT report, BRT in Chinese cities currently assumes one of the following roles in serving as an urban public transport system (CATS 2016):

1. The city has an established BRT network that serves as the primary mode of public transport (e.g., Jinan and Urumqi).
2. BRT is deployed as a transitional or extended transport mode for light rail or subways (e.g., Line 1 of the elevated Xiamen BRT was designed with the same specifications as light rail and can be readily upgraded in the future).
3. BRT and rail systems coexist on equal footing, forming the intricate fabric of urban transport system in the city (e.g., Guangzhou).
4. The city has one or more independent corridors that can potentially evolve into a BRT network (e.g., Dalian, Hangzhou, and Hefei).

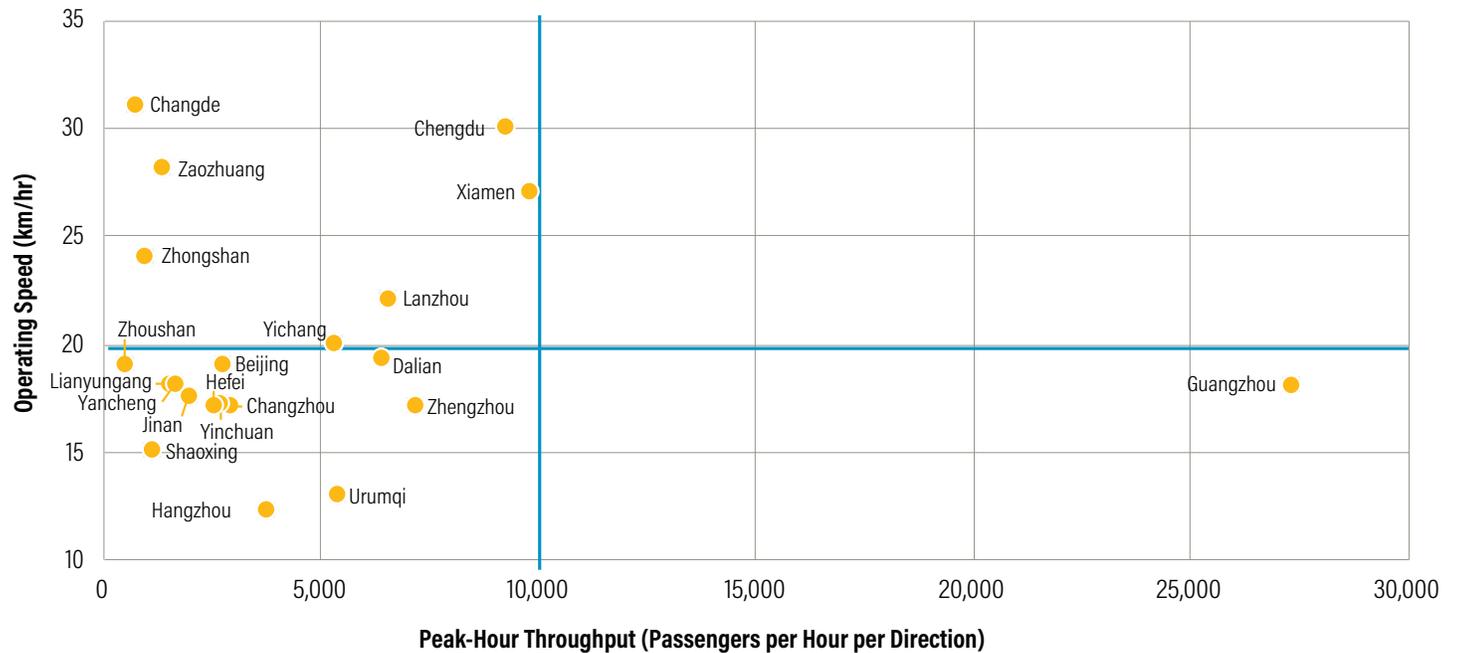
As seen in Table 1, BRT systems are implemented in a wide range of Chinese cities, and their design components vary from one city to another. The design elements in Table 1 were selected because they are considered vital components for a BRT (see Box 1 and Box 2).

Table 1 | Features of Bus Rapid Transit in 24 Chinese Cities

CITY	CITY POPULATION	RIDERSHIP (PASSENGERS PER DAY)	DESIGN FEATURES			
			100% Exclusive Lanes	Location of Busways	Passing Lane	Pre-boarding Fare Payment System
Guangzhou	8,483,000	850,000	✓	Median aligned	✓	✓
Zhengzhou	8,022,700	650,000	✗	Median aligned and curbsides	N/A	✓
Urumqi	2,668,700	380,000	✗	Median aligned and curbsides	Partial	✓
Changzhou	3,697,500	350,000	✗	Median aligned	✗	✓
Xiamen	2,072,900	340,000	✗	Elevated road	Partial	✓
Beijing	13,393,000	305,000	✗	Median aligned	✗	✓
Lanzhou	3,217,700	290,000	✗	Median aligned	✓	✓
Chengdu	12,193,900	278,200*	✓	Elevated road	✗	✓
Hangzhou	7,196,600	260,000	✗	Median aligned and curbsides	✗	✓
Yichang	4,109,800	240,000	✗	Median aligned	✓	✓
Jinan	6,236,700	220,000	✗	Median aligned	✗	✓
Liuzhou	3,797,800	99,600*	✗	N/A	N/A	✓
Dalian	5,939,300	87,000	✗	Median aligned and curbsides	✗	✓
Yinchuan	1,776,200	87,000	✓	Median aligned	✗	✓
Hefei	7,152,600	65,250	✓	Median aligned	✗	✓
Yancheng	8,282,900	33,000	✓	Median aligned	✗	✓
Zhongshan	1,573,700	33,000*	✗	Median aligned	✗	✓
Changde	6,089,100	30,700*	✓	Median aligned	✗	✓
Zaozhuang	4,055,500	30,000	✗	Median aligned and curbsides	✗	✓
Lianyungang	5,285,400	20,000	✓	Median aligned	✗	✓
Shaoxing	4,430,700	11,600*	✗	Lack effective segregation	✗	✓
Zhoushan	974,300	10,900*	✗	Next to bike paths and curbsides	✗	✓
Jining	8,637,800	2,500*	✗	N/A	N/A	✓
Jinhua	4,765,700	2,100*	✗	N/A	N/A	✓

Sources: City population is based on "Annual Average Population" of "Total City" from *China City Statistical Yearbook 2016* (National Bureau of Statistics of China 2016). Design features are adapted from MOT (2016). Ridership information is taken from BRT Centre of Excellence et al. (2017), except the ones with an *, which are taken from MOT (2016).

Figure 2 | Operating Speeds and Peak-Hour Throughput of Bus Rapid Transit in China



Sources: Data from ITDP (2014c) and CATS (2016); compiled by the authors.

Additionally, more than 10 cities—including Dandong, Guiyang, Harbin, Wuhan, Yingkou, and Zhuzhou—are planning to build BRT in their cities, while Chengdu, Urumqi, Yichang, and Zaozhuang are considering expanding their existing BRT systems (authors’ survey).

Challenges and Opportunities for BRT Systems in China

There are several ongoing challenges when it comes to the development of BRT systems in China. First, despite the successes of the Guangzhou and Yichang systems, BRT is still a relatively unfamiliar concept to many Chinese decision makers, and therefore they are hesitant to invest in BRT. The term *rapid transit* is often associated with rail-based—rather than bus-based—services that signify “modern, advanced technology [and offer] politicians tangible, highly visible achievements to impress their constituencies and the rest of the world” (Pucher et al. 2007, 400). While metro can provide a great experience (fast, high capacity, frequent, often reasonably comfortable) for long-distance trips or those that are conveniently aligned with the orientation of a line in the network, covering the whole city with metro lines that could serve every trip would be extremely costly. Besides, metros are quite rigid in the sense that rail tracks

cannot be moved around, so trains stick to the line they are operating. For various passenger trips that metros are difficult to cover, other public transport modes such as BRT can be part of the multimodal solutions for the city.

Second, when the lanes are dedicated for moving BRT buses, private car owners perceive that their space is reduced and therefore that BRT contributes to and exacerbates traffic congestion. The general public also often has the negative perceptions of BRT that are associated with conventional buses, such as experiencing delays (Deng et al. 2013; Zeng 2013). Only when systematic benefits of BRT (such as convenience) become evident to the residents do public opinions begin to change, as witnessed in early Hangzhou BRT implementation (Zeng 2013) and a Guangzhou BRT satisfaction survey in 2014 (ITDP 2014b). This makes it all the more necessary to deliver high-quality BRT design, as bad experiences can create public resistance to expansion of BRT systems.

No single mode of transport can sustainably serve the diverse mobility demands needed in growing cities; instead, a combination of different modes is needed. Given the existing opportunities for and obstacles to implementing BRT in China, one of the most reasonable measures would be to deliver the true potential of BRT

in Chinese cities and provide high-quality BRT services to overcome misconceptions and biases against BRT as a viable mode of transport.

Preliminary Assessment of BRT Systems in China

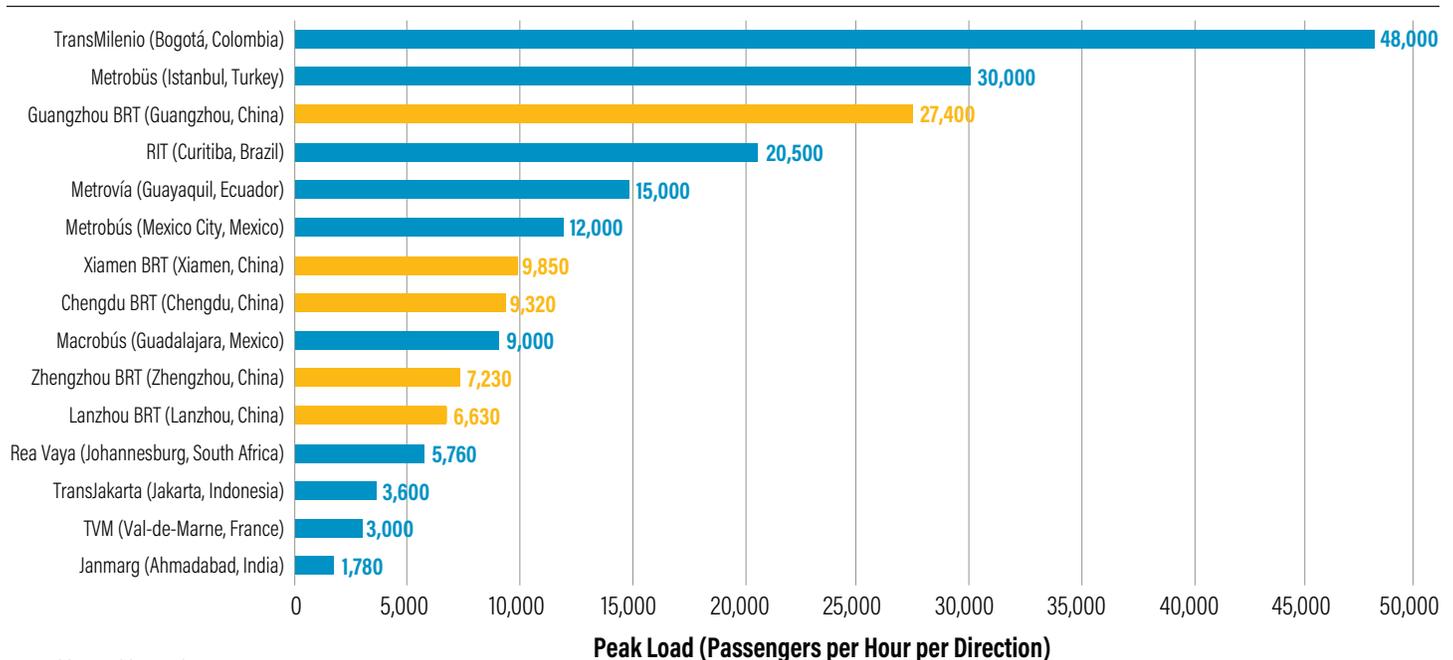
Currently, few BRT systems in China reach over 10,000 passengers per hour per direction (pphd) of peak throughput, and many run under the *operating speed* of 20 km/hr (Figure 2). Operating speed is defined as the average BRT bus speed of the system, accounting for the dwell time spent for passenger boarding and disembarking at stations; *peak throughput* (or *peak load*) is defined as the maximum number of passengers transported in one direction in one hour between two BRT stations (BRT Centre of Excellence et al. 2017). Both are often considered as important BRT performance measures (Carrigan et al. 2013; CATS 2016; Herrera et al. 2016), and their merit is further explained in Box 2. Generally, BRT systems are considered to have high speed if they operate between 20 km/hr and 35 km/hr and have high capacity if they can reach peak ridership between 15,000 and 25,000 pphpd (CATS 2016). Figures 3 and 4 illustrate how the top five systems in China perform—in terms of throughput and speed, respectively—in comparison with selected BRT systems around the world.

Fjellstrom (2010) examined the evolution of BRT systems in China and categorized them into four generations—ranging from the earliest proto-BRT busway in Kunming in 1999 to the high-speed, high-capacity Guangzhou BRT in 2010. He found that BRT systems in Hangzhou, Xiamen, Dalian, Kunming, and Changzhou experienced capacity constraints in terms of bus volumes and passenger waiting area as a result of BRT station design, which did not foresee large passenger demand levels.

There are several comparative assessments of international BRT systems, some of which include Chinese systems. Hidalgo and Graftieux (2008) reviewed BRT corridors in 11 cities of Latin America and Asia and reported that the corridors have a throughput range of 3,000 to 45,000 pphpd. Similar to Fjellstrom (2010), the authors also concluded that many BRT systems, including Beijing BRT, had capacity issues in terms of station size and bus fleet capacity and were therefore experiencing overcrowding during peak hours.

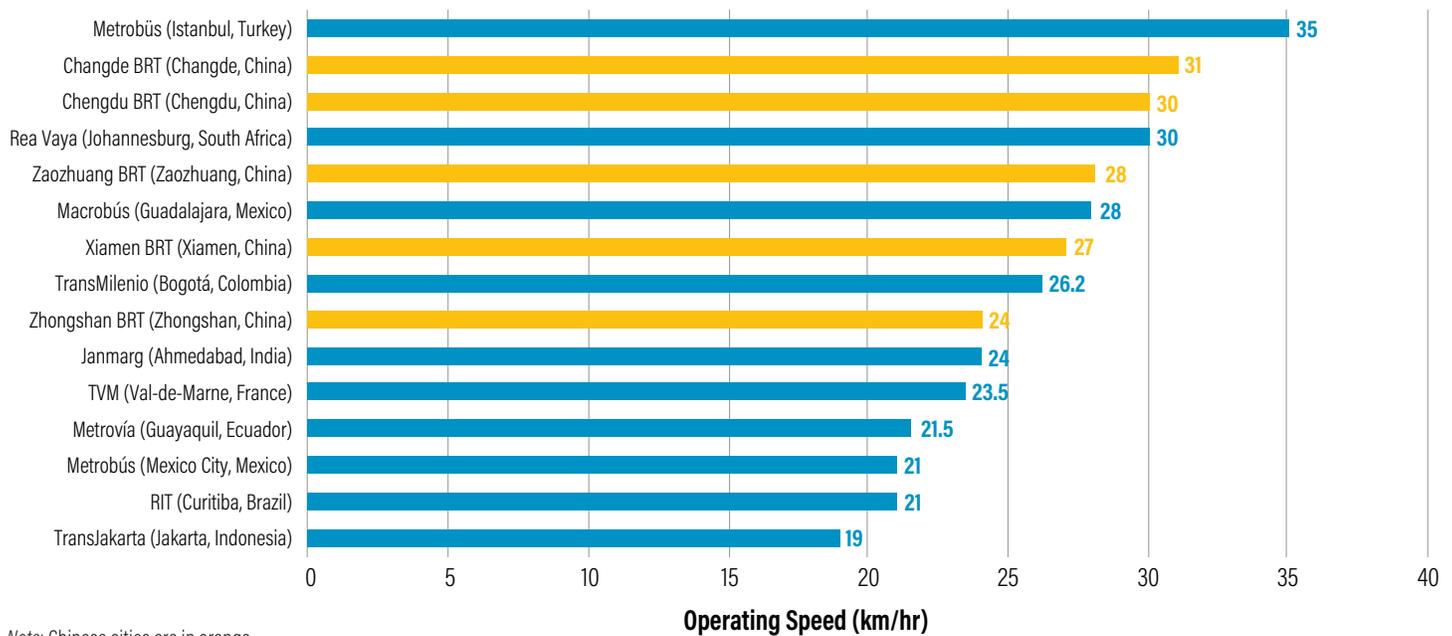
In another study of 13 Chinese and 9 Latin American BRT systems, Deng et al. (2013) found that Chinese systems have almost 2.5 times less peak-hour ridership than their counterparts. According to the authors, the reasons for the lower ridership could be that BRT systems in China

Figure 3 | Peak-Hour Throughput of Selective International and Chinese Bus Rapid Transit Systems



Note: Chinese cities are in orange.
Sources: Data from ITDP (2014c) and CATS (2016).

Figure 4 | Operating Speeds of Selective International and Chinese Bus Rapid Transit Systems



Note: Chinese cities are in orange.

Sources: Data from BRT Centre of Excellence et al. (2017) and ITDP (2014c).

implement fewer passing lanes (an additional lane at stations to enable buses to overtake each other) and stopping bays (designated areas for buses to pull away from traffic flow to pick up passengers), both of which can help increase corridor capacity and accommodate larger passenger throughput.

Since the deployment of BRT design elements substantially impacts BRT performance and service quality (see Box 2), the purpose of this paper is to perform a comparative benchmark analysis among design elements between Chinese and international BRT systems to ensure that Chinese systems meet and surpass international standards. The international community can, in turn, learn from BRT designs and practices in China. Many partnerships, in fact, have been established between Chinese decision makers and international organizations (e.g., WRI and the China Urban Sustainable Transport Research Center), and a great deal of knowledge sharing (e.g., via site visits to South American and Chinese BRT systems) is already taking place. This document aims to contribute to and augment these real-world learning experiences.

3. REVIEW OF THE LITERATURE

High quality or performance is related to how BRT systems are designed (Carrigan et al. 2013; Herrera et al. 2016), and successes (and failures) of such systems as a result of BRT design features are well documented in the literature (a brief explanation of the importance of design elements for BRT performance can be found in Box 2). Unfortunately, among the studies that focus on BRT design, few have performed formal statistical analyses to comparatively evaluate global BRT systems (e.g., Hensher and Li 2012, as explained below). For this research gap, we identify two central barriers that make formal quantitative evaluations difficult.

The first is that many physical and operational elements can influence BRT performance. Lindau et al. (2013), for instance, presented 10 key elements that are likely to have impacts on system performance, including traffic signal times and coordination, distance between stations, and interface between buses and stations. Based on the evaluation of BRT systems in 13 Chinese cities, Deng et al. (2013) provided evidence that overtaking lanes have a statistically significant impact

on peak ridership and frequency, while long station spacing has a significant positive impact on peak-hour operating speed. Interestingly, they found no statistical significance between system performance and population or population density of Chinese cities. In another study, Herrera et al. (2016) selected broader BRT design characteristics that can greatly affect the performance of a BRT corridor: closed versus open system, corridor type, station type, operation, vehicle technology, intersection type, and control systems.

The second obstacle that explains why few studies have conducted quantitative comparisons of global BRT systems is the lack of reliable and comprehensive data; usually, available data are piecemeal, gathered by various researchers using different methodologies. For example, drawing from various sources—including direct contact with BRT operators, BRT websites, and BRT planning specialists such as EMBARQ/WRI and ITDP-China—Hensher and Li (2012) gathered information for 46 BRT systems in 15 countries and performed a statistical analysis. Using such a large data set, the authors studied one dimension of BRT performance that they think is particularly meaningful: passenger patronage. They identified that headway, the length of BRT network, fare, modal integration at stations, and the average distance between BRT stations have a statistically significant influence on the number of daily BRT passengers.

In light of the two obstacles (limited data and many influencing factors), our approach is to use the *BRT Standard* from the ITDP, a publicly accessible database that evaluates BRT corridors based on a variety of metrics to provide a common understanding of BRT by international BRT experts and practitioners (ITDP 2014a). According to the ITDP, the scores in the *BRT Standard* are appraised based on the design characteristics of a BRT corridor that “most significantly improve operational performance and quality of service” (ITDP 2014a, 9). We use the *BRT Standard* for our analysis for its standardized and robust scoring rubric that is applicable to a wide range of global BRT contexts and therefore allows us to perform consistent benchmarking analyses of design elements between BRT systems in China and international systems.

4. METHODOLOGY

For the benchmarking analysis, we use the *BRT Standard* from the ITDP and apply the statistical analysis of variance (ANOVA) method (Miller 1997) to a wide range of global BRT systems. Specifically, the paper relies on 99 BRT corridors and systems (including 23 data points from 18 Chinese cities) appraised by the ITDP in 2013 and 2014 (the summary of the scoring categories can be found in the Appendix; additionally, details of how the scores are established can be found in ITDP [2013] and ITDP [2014a]). This document, to our knowledge, is among the first to utilize the *BRT Standard* to comparatively evaluate Chinese and international BRT systems.

Benefits and Challenges of Using the *BRT Standard*

The *BRT Standard* was employed for the working paper because it consistently measures and documents a wide range of BRT metrics, which are agreed upon by global BRT experts, for a substantial number of international BRT systems. Points in the appraisal system should also act as proxies for high-quality BRT service for passengers (ITDP 2014a)—that is, the points should reflect the attributes discussed in Box 2 (comfort, reliability, etc.). Moreover, since evaluations are clearly defined and public, making them independently verifiable, the *BRT Standard* can serve as a technical decision-making tool to help city governments in the BRT design process (ITDP 2014a).

There are three main caveats to using the *BRT Standard*, however. First, while the *BRT Standard* was created to establish a common understanding of what constitutes a quality BRT, the ITDP quantifies and defines BRT in a specific manner (Box 3 explains this definition). As discussed in Box 1, BRT experts have not reached a consensus definition of BRT. While the definition from the *BRT Standard* does exceptionally well in capturing many significant BRT systems around the world, the very act of drawing a concrete line in designating what qualifies as a BRT means there is an inevitable chance of disregarding a small minority of bus systems.

Second, the ITDP recommends that the *BRT Standard* be applied to specific “corridors” rather than to a BRT “system” as a whole because BRT corridors within the same city can have varying qualities (Herrera et al. 2016).

Box 2 | Key Features of a Bus Rapid Transit System

To realize its potential of providing metro-like service at the surface, bus rapid transit (BRT) should lower travel times, be comfortable for users, facilitate low waiting times, and be reliable—since these attributes, among others, can affect users' perceived level of service (Raveau et al. 2016). Such BRT service can be achieved by increasing operating speed, increasing frequency, increasing capacity, and having regular headways (Muñoz 2015). Figure B2.1 illustrates some factors and key attributes:

- To have a fast service, the operating speed needs to increase.
- To lower waiting time, buses need to pass by more frequently and at regular time intervals (headways).
- To make the system more comfortable for a given demand level, passenger capacity has to increase.
- To have more reliability, headways need to be as regular as possible. Regular headways, by definition, mean low headways and can result in an increase in frequency as well as capacity.

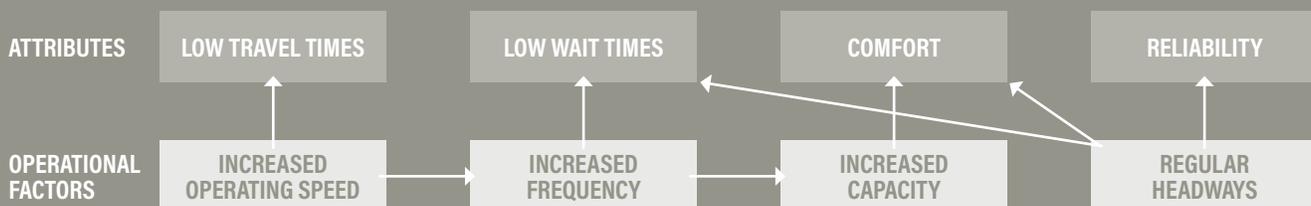
The four factors are also interrelated:

- Increasing operating speed enables higher frequencies because the same number of buses can go through more cycles per hour. This also increases the capacity of the system (measured in passengers per hour per direction and calculated as the product of frequency and the average passenger capacity of each vehicle).
- Having regular headways (e.g., by having centralized control of traffic signal priority systems) helps reduce bus bunching, a phenomenon in which buses belonging to the same service arrive at the same time at the same station.
- A system in which buses have regular headways (i.e., buses are evenly spaced) is reliable and has lower waiting times. This allows passengers to randomly arrive at stations without needing to consult the schedule (Frumin and Zhao 2012). Such a system is also more comfortable for passengers who are better distributed in each bus, therefore lowering the passenger density at the station and in the vehicles (Delgado et al. 2016).

Actions that can be taken to influence the performance of a BRT system include the following:

- **Implement segregated lanes to avoid mixing BRT buses with general traffic:** This increases average speed by isolating bus operation from vehicle congestion (Carrigan et al. 2013; Cervero 2013; Lindau et al. 2013).
- **Incorporate traffic signal priority and other intersection treatments:** This helps increase the average speed of the buses and maintain headway regularity along the route by reducing delays at intersections (Delgado et al. 2012; Herrera et al. 2016; Janos and Furth 2002).
- **Implement express services:** These services enable BRT buses to skip some stations along the corridor in order to increase speed and save travel time. They are particularly effective in corridors with high and unbalanced demand, in which passengers usually make long trips. Express services usually require passing lanes at stations so buses can overtake each other (Larraín et al. 2010).
- **Provide measures such as pre-boarding fare payment and having buses with multiple doors:** This can reduce time spent at the BRT stop or dwell time (Cervero 2013; Lindau et al. 2013).

FIGURE B2.1 | INFLUENCE DIAGRAM: DESIRABLE ATTRIBUTES IN A BRT SYSTEM AND FACTORS TO ACHIEVE THEM



Source: Muñoz 2015.

However, due to difficulties in gathering data and defining what a corridor is, the ITDP appraised several BRT “systems” in 2013. Because those evaluations are few in number, we did not distinguish between a BRT evaluated at the corridor or system level but instead included all the available data points from the ITDP as “BRT observations” or “BRT corridors/systems.” This is another limitation in the analysis conditioned on the ITDP’s evaluation guidelines.

Finally, the scoring rubric in the *BRT Standard* includes no infrastructure or operation costs—which are often crucial considerations for planners and decision makers when it comes to prioritizing investments. The ITDP instead suggests complementing the *BRT Standard* with other cost-effective tools to avoid underestimating capital investments needed for BRT performance and

Box 3 | **BRT Standard Definition of a Bus Rapid Transit Corridor**

In the 2013 edition of the *BRT Standard*, a bus rapid transit (BRT) corridor is defined as “a section of a road or contiguous roads served by a bus route or multiple bus routes that have dedicated lanes with a minimum length of 4 kilometers” (ITDP 2013, 14). Later in 2014, the defined length was reduced to 3 kilometers in order to be able to qualify BRT systems in downtown areas (ITDP 2014a). The ITDP’s definition of what is (and is not) a BRT corridor is illustrated in Figures B3.1 and B3.2.

The *BRT Standard* considers five basic elements that are essential for a BRT system (ITDP 2013, 2014a):

- Dedicated right-of-way
- Busway alignment
- Off-board fare collection
- Intersection treatments
- Platform-level boarding

In order to emphasize the essential features of a BRT system, the total available score for the five elements was increased from 38 points in the 2013 edition to 43 points in the 2014 edition by adding an extra point to each of the five components (ITDP 2014a).

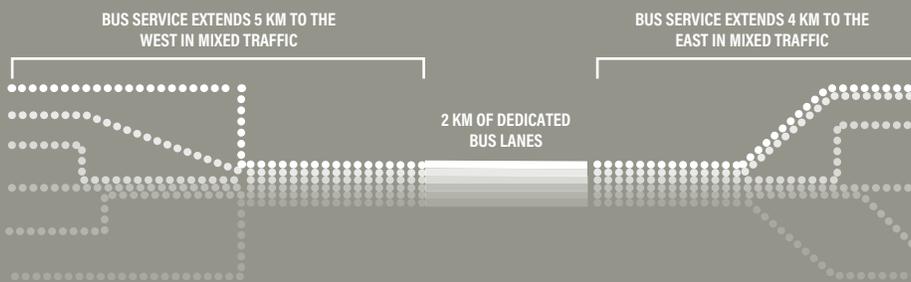
To be qualified as BRT, the corridor must obtain at least 4 points for both dedicated right-of-way element and busway alignment element (ITDP 2013, 2014a). Additionally, in the 2013 edition, it must score an overall minimum of 18 points across the five basic elements (ITDP 2013). In the 2014 edition, this total minimum score was increased to 20 points (ITDP 2014a). The detailed scoring system for both years can be found in the Appendix.

FIGURE B3.1 | EXAMPLES OF A 3-KILOMETER CORRIDOR



Source: ITDP 2014a.

FIGURE B3.2 | EXAMPLE OF WHAT IS NOT A BRT CORRIDOR



Source: ITDP 2014a.

incurring higher operating costs in the long run (ITDP 2014a). Indeed, BRT costs vary widely from one city to another, depending on different contexts. However, since

high-quality data for such information is not readily available, especially for our benchmarking BRT systems, we unfortunately must leave these aspects out of the scope of this study.

Applying ANOVA

Score indicators from the *BRT Standard* are made up of seven categories: BRT basics, service planning, infrastructure, stations, communications, access and integration, and point deductions. The categories are further disaggregated into 38 subcategories (see the Appendix for the complete list of subcategories, along with their maximum available scores). Indicators from the first six categories (and their subcategories) consist of design characteristics that are commonly associated with high BRT performance (ITDP 2014a). In attempting to capture multifaceted benefits of BRT, the *BRT Standard* also includes indicators such as minimizing bus emissions, branding, passenger information, and universal access, which might not have a clear direct influence on conventionally defined BRT performance (speed, throughput, time saving, etc.). These features, however, embody the internationally well-accepted BRT best practices, and therefore we use all 30 indicators from the six categories as potential candidates for our comparative analysis. In contrast, we exclude the indicators from the point deductions category, which was created to penalize significant BRT operation weaknesses and thus does not reflect design characteristics.

Since the *BRT Standard* is reviewed and updated on a regular basis by a technical committee, we transformed the evaluations from the 2013 edition in accordance with the 2014 edition for the analysis and ensured that they are still comparable for the analysis. For example, consider the two Chinese BRT corridors, Beiyuan Dajie and Changde Dadao (in the cities of Jinan and Changde, respectively), evaluated in 2013 and 2014 for the BRT basics category. The maximum achievable score for this category was increased from 33 points in 2013 to 38 points in 2014. After transforming to the new standardized scale, the Beiyuan Dajie corridor that received 25 points (out of 33) in 2013 earned 75.7 points (out of 100) for the BRT Basic category in 2014. The Changde Dadao corridor, with its 27-point score (out of 38) in 2014, would receive 71.1 points for the same category. Thus, in comparison, the Beiyuan Dajie corridor achieved a better score than the Changde Dadao.

For the comparative analysis, the BRT observation points are then separated into a target group (the Chinese BRT systems with 23 observations that are listed in Table 2) and benchmark group (international BRT systems with

76 observations). For each of the 30 design elements, we employ the ANOVA method with a 95 percent confidence interval to determine if there are any statistically significant differences between the means of target and benchmark groups (Miller 1997). Mathematically, the mean score of the target and benchmark groups can be expressed as follows:

EQUATION 1: AVERAGE SCORE TARGET GROUP

$$\bar{S}_{i,tg} = \sum_{t \in T} \sum_{j \in N_{tg}} \left(\frac{S_{i,j,t}}{m_{i,t}} \right) / N_{tg}$$

EQUATION 2: AVERAGE SCORE BENCHMARK GROUP

$$\bar{S}_{i,bg} = \sum_{t \in T} \sum_{j \in N_{bg}} \left(\frac{S_{i,j,t}}{m_{i,t}} \right) / N_{bg}$$

WHERE

- $\bar{S}_{i,tg}$ Average percentage score in subcategory i within the target group
- $\bar{S}_{i,bg}$ Average percentage score in subcategory i within the benchmark group
- $S_{i,j,t}$ Score in subcategory i of the BRT corridors/systems j evaluated in year t
- $m_{i,t}$ Maximum score in subcategory i defined for the year t
- N_{bg} BRT corridors/systems in the benchmark group
- N_{tg} BRT corridors/systems in the target group

BASED ON THE ANOVA TEST FOR THE DIFFERENCE BETWEEN $\bar{S}_{i,tg}$ AND $\bar{S}_{i,bg}$ ($\Delta\bar{S}_i$), THERE ARE THREE POSSIBLE OUTCOMES:

- a. $\Delta\bar{S}_i$ is positive and significantly different from zero
- b. $\Delta\bar{S}_i$ is negative and significantly different from zero
- c. $\Delta\bar{S}_i$ is non-significantly different from zero (undetermined)

Case (a) represents the design indicators where the target group, on average, is comparatively better in the BRT design element, whereas case (b) represents those in the target group that, on average, are lagging behind the benchmark group. In both cases, there is a 95 percent likelihood that these differences are not due to random chance alone. In case (c), we cannot make any statistical inferences regarding the score difference between the two groups and therefore cannot conclude if Chinese systems are better or worse than ones in the rest of the world.

Table 2 | Chinese Bus Rapid Transit Systems Included in the Analysis

YEAR	CITY	SYSTEM	CORRIDOR
2013	Beijing	Beijing BRT	Entire network
2013	Changzhou	Changzhou BRT	Entire network
2013	Guangzhou	Guangzhou BRT	Zhongshan Avenue
2013	Jinan	Jinan BRT	Beiyuan Dajie
2013	Jinan	Jinan BRT	Lishan Lu
2013	Jinan	Jinan BRT	Erhuandonglu
2013	Jinan	Jinan BRT	Gongyebeilu-Aotizonglu Line 6
2013	Lanzhou	Lanzhou BRT	Anning Lu
2014	Changde	Changde BRT	Changde Dadao
2014	Chengdu	Chengdu BRT	Erhuan Lu
2014	Dalian	Dalian BRT	Zhangqian Lu–Songjiang Lu–Huabei Lu–Xi’an Lu
2014	Hefei	Hefei BRT	Hefei Line 1 (Changjiang)
2014	Jinan	Jinan BRT	B7 corridor Xierhuan
2014	Lianyungang	Lianyungang BRT	Xingfu-Hailian-Xingangcheng-Gangcheng
2014	Urumqi	Urumqi BRT	Corridor 1 (Beijinglu-Xibeilu-Yangzijiangu)
2014	Xiamen	Xiamen BRT	(No corridor name)
2014	Yancheng	Yancheng BRT	Kaifang Dadao–Jiefang Nanlu
2014	Yinchuan	Yinchuan BRT	Huanghe East–Nanxun–Qinghe
2014	Zaozhuang	Zaozhuang BRT	B1
2014	Zaozhuang	Zaozhuang BRT	B3
2014	Zaozhuang	Zaozhuang BRT	B5
2014	Zhengzhou	Zhengzhou BRT	(No corridor name)
2014	Zhongshan	Zhongshan BRT	Zhongshan 2nd–5th Road–Jiangling Road

Source: ITDP 2014c.

5. FINDINGS AND THE WAY FORWARD

Findings

Among 21 countries evaluated by the ITDP in 2013 and 2014, China received the sixth-lowest score, with the average BRT systems in China scoring 7 points lower than the world BRT average. As seen in Figure 5, 18 of 30 subcategory indicators show statistically significant differences between Chinese and international systems. Chinese systems exhibit statistically significant higher scores in 7 subcategory indicators and statistically significant lower scores in 11 subcategories. BRT systems in China also receive higher scores in many design indicators that are not statistically significant (such as platform-level boarding and integration with other public transport).

Beyond identifying which subcategories have statistically significant differences between Chinese and international BRT systems, the benchmarking analysis does not provide definitive priority order of importance among different indicator features for BRT systems in China. First, there can be interdependencies among different indicators (e.g., express services rely on the provision of passing lanes), and the influence of the combination of design elements on BRT performance greatly depends on urban contexts (as illustrated in Herrera et al. 2016). Second, while BRT best practices such as minimizing bus emissions underscore the role of BRT in emission reduction as a public transport mode, they might not necessarily change the users’ perceived quality of service or BRT performance. Nevertheless, all indicators reveal that there is a significant gap between Chinese and international BRT systems.

Subcategories in Which China Scores above the International Mean

The subcategories in which Chinese BRT systems achieved scores statistically significant higher than the international mean included the following (in no particular order):

- Off-board fare collection, which helps reduce dwell time (the time BRT buses spend at the stations) and therefore reduces the overall travel time
- Control center, which monitors and provides real-time responses to the BRT system (such as controlling the vehicle spacing, responding to incidents or emergencies, or recording passenger boarding/disembarking information) using the Global Positioning System, cameras, and other technologies
- Hours of operation, which measures if a BRT system offers services during as many hours as possible, including both late-night hours and weekend services

Figure 5 | Chinese and International Bus Rapid Transit: Findings from Analysis of Variance

CATEGORY	INDICATOR	PERIOD 2013-14
BRT basics	Off-board fare collection	25.7
	Platform-level boarding	13.4
	Busway alignment	0
	Dedicated right-of-way	-1.3
	Intersection treatments	-65
Service planning	Control center	20.2
	Hours of operation	10
	Multiple routes	8.3
	Located in top 10 corridors	-13.4
	Multicorridor network	-21.1
	Express, limited, and local services	-24.8
	Demand profile	-54.6
Infrastructure	Pavement quality	24.1
	Center stations	16.5
	Minimizing bus emissions	-29.3
	Passing lanes at stations	-31.4
	Stations set back from intersections	-54.1
Station design and station-bus interface	Sliding doors in BRT stations	41.8
	Number of doors on bus	14.1
	Safe and comfortable stations	10.6
	Docking bays and substops	-7.2
	Distances between stations	-27.7
Communications and marketing	Passenger information	18.2
	Branding	9.1
Integration and access	Bicycle lanes	24.5
	Integration with other public transport	13.1
	Bicycle-sharing integration	1.7
	Secure bicycle parking	-7.1
	Pedestrian access	-35.5
	Universal access	-70.6

Statistically significant difference

Yes No

Notes: Sample size: 99 data points (target group with 23 observations and benchmark group with 76 observations). Positive significant difference means BRT systems in China, on average, are comparatively better than international systems. Negative significant difference means Chinese BRT systems, on average, are lagging behind global systems. There is a 95 percent likelihood that these differences are not due to random chance alone.

Source: Data from ITDP (2014c); analysis done by the authors.

- Pavement quality, which ensures the pavement structure is designed for a long life span without the need for frequent repairs on the busway
- Sliding doors in BRT stations, which protects passengers from accidents as well as unauthorized entry to the BRT station
- Passenger information, which provides users with up-to-date static messages or real-time dynamic messages of when the next bus is coming or what the next stop is
- Bicycle lanes, which evaluates whether the BRT system integrates bicycle lane networks in order to be able to provide comprehensive sustainable travel options

Subcategories in Which China Scores below the International Mean

Next, we examine the indicators in which BRT systems in China receive lower scores than international counterparts (Table 3). In order to understand why there is a statistically significant gap, we also look into the scores of specific Chinese systems.

Discussion and Recommendations

This section focuses on how to improve the design characteristics for which BRT systems in China obtained statistically significant lower scores than their international counterparts. While the lessons that can be helpful for the new generation of BRT systems in China are primarily drawn from successes and challenges of existing systems within the country, we also incorporate findings from global BRT cases from which Chinese BRT systems can benefit.

Because the deployment of BRT is contingent upon the varying urban contexts of each Chinese city as well as local institutions, the recommendations in this subsection are mainly intended to be illustrative rather than exhaustive. Additionally, because of the political fragmentation and complex institutional structure, the interests of various Chinese government stakeholders—transport commissions, construction bureaus and design institutes, and traffic police—in BRT projects are all different. Further studies into these political entities in different phases of BRT deployment are warranted to enable recommendations on the most feasible policies that can be adopted in each city. The primary purpose of this working paper is to identify areas of improvement for BRT systems in China, and therefore we do not further explore the subcategories in which Chinese systems scored statistically higher.

Since we mainly used the *BRT Standard* as our analysis tool because of its consistent appraisal of BRT characteristics, our current research is, to a great extent, defined by the *BRT Standard*'s rubric. While this rubric is not specifically designed for our working paper, we found during our research process that the *BRT Standard* could expand its evaluations to include other indicators, such as an affordability index and the influence of urban configurations on BRT corridors. In this light, one of the areas for future research is to employ other accepted methodologies to perform analysis on a more comprehensive set of BRT characteristics.

Below, seven design-related indicators that can affect BRT performance are discussed. However, we do not include location in top 10 corridors, one of the indicators for which Chinese BRT systems received statistically significant lower scores, because only 4 observations (out of 23) in China did not obtain full scores, and the negative significance was the algebraic result of the overwhelming number of international BRT systems receiving higher scores for the BRT indicator. We then discuss three additional indicators—minimizing bus emissions, pedestrian access, and universal access—which are internationally recognized as best practices emphasizing environmental and social benefits of BRT systems.

Design Indicators

INTERSECTION TREATMENTS

Intersection treatments are one of the fundamental design elements essential to be qualified as a BRT system by the *BRT Standard* (Box 3) as well as the international BRT community. Intersections are hot spots where BRT buses can spend significant time idling, while various transport modes also interact and converge. If not properly treated, they can contribute to traffic congestion, create traffic safety risks, and often exacerbate operation problems such as bus bunching, when buses of the same route arrive simultaneously at the same station or stop. For example, Zhang et al. (2013) point out that BRT buses in Beijing, Jinan, and Zhengzhou encountered delays at intersections, contributing to almost half of the journey time. At the same time, BRT buses (as well as other transport modes) must be cognizant of pedestrian safety when considering increasing speed and providing faster service.

Table 3 | Indicators on Which Chinese Bus Rapid Transit Systems Receive Lower Scores

INDICATOR	DESCRIPTION
Intersection treatments	The intersection treatments indicator belongs to the BRT basics category, which is considered essential in defining a bus corridor as BRT in the <i>BRT Standard</i> . Most BRT systems in China scored 0 for this subcategory, indicating that many systems in China do not have intersection treatments at all.
Located in top 10 corridors	The located in top 10 corridors indicator indicates that the BRT corridor is situated along one of the 10 highest corridors in terms of bus ridership. Only four BRT data points in China do not obtain full scores. A possible explanation for the negative significant difference is that the overwhelming majority of international BRT systems exist along cities' highest-demand corridors.
Multicorridor network	The multicorridor network indicator evaluates whether multiple BRT corridors intersect and create a network. Approximately 40% of the BRT in China in the ITDP database did not receive points for this indicator. Some systems in China that received a full score include Jinan BRT, Xiamen BRT, and Zaozhuang BRT.
Express, limited, and local services	The majority of BRT systems in China do not provide express or limited-stop services. Only the Line 1 corridor in Zaozhuang, the Zhongshan Avenue corridor in Guangzhou, and the Xiamen BRT accommodate some form of such services.
Demand profile	In China, many BRT systems often operate in mixed traffic conditions in the road segments with high demand without implementing a fully segregated bus lane; thus, they experience delays and congestion. The ITDP's <i>BRT Standard</i> scores 0 points for such systems, and, as a result, BRT corridors in China perform significantly worse than their international counterparts in the demand profile subcategory. An exemplar Chinese BRT that received a full score is Guangzhou BRT.
Minimizing bus emissions	The minimizing bus emissions indicator evaluates the acceptable limits for bus tailpipe emissions (in particular, particulate matter [PM] and nitrogen oxides) based on the emission standards of Europe and the United States. According to the evaluation, Chinese BRT buses meet any of the following three conditions: <ul style="list-style-type: none"> ■ The buses must meet the European standards Euro IV or V but with no PM filters, which are important for reducing PM emissions. ■ The buses use compressed natural gas (instead of diesel) and meet Euro III. ■ The buses meet Euro III and have certified PM filter retrofit.
Passing lanes at stations	A few BRT corridors in China that offer full passing lanes include the Zhongshan Avenue corridor in Guangzhou and the Anning Lu corridor in Lanzhou.
Station set back from intersections	Almost half of BRT data points in China received a score of 0; that is, in these corridors fewer than 25% of the stations satisfy the suggested minimum setback length of 26 meters. Only 6 out of 23 observations in the database received full points by having more than 75% of their stations satisfy the ideal setback length of 40 meters or by having segregated busways with no intersections. These observations correspond to the cities of Chengdu, Dalian, Guangzhou, Hefei, Lanzhou, and Xiamen.
Distances between stations	A full score is rewarded if BRT stations are, on average, located between 300 meters and 800 meters apart. Approximately 43% of the observations in the database received a score of 0. Some of these BRT systems are the Changde Dadao corridor in Changde; the Zhangqian Lu–Songjiang Lu–Xi'an Lu corridor in Dalian; and the B1, B3, and B5 corridors in Zaozhuang.
Pedestrian access	Only two Chinese BRT corridors, the BRT-7 corridor in Jinan and Zhongshan BRT, earned full scores for the pedestrian access indicator, whereas 30% of total BRT systems assessed received a score of 0. Compared to their international counterparts, however, corridors in China, on average, received a higher score for the integration with other public transport subcategory, but the difference is not statistically significant.
Universal access	For the universal access indicator, the majority of BRT systems in China received a score of 0, indicating that many Chinese BRT buses and stations do not provide access to all types of passengers (the elderly, children, people in wheelchairs, and other passengers with special needs).

Some approaches to implementing better intersection treatments include employing transit signal priority (TSP) systems for BRT buses, which can be especially useful in systems or at times when bus frequency is relatively low; simplifying allowable traffic movements through the intersection—for example, by precluding all or most turns across the BRT lanes; and incorporating grade-separated junctions to eliminate the conflict between the corridor and cross streets.

TSP enables BRT vehicles to reduce the number of junctions where they have to stop by increasing the likelihood of buses having a green light when they reach the intersection. However, previous research has acknowledged the difficulty of TSP implementation in China due to high-volume, widely varied traffic flows between motorized and nonmotorized modes at the intersections (Chen et al. 2008). Likewise, Deng et al. (2013) found that TSP systems for Beijing Line 1, which can help reduce congestion and delays at intersections, were not working correctly.

The ITDP's *BRT Standard* advises that while TSP is a good approach for lower-frequency BRT systems, it can be less effective than complete turn prohibitions (ITDP 2014a). Zhongshan Avenue BRT in Guangzhou has prohibited all turns along the 23-kilometer busway and therefore received a full score for the subcategory. Yichang BRT has implemented dynamic traffic signal phase timings on Dongshan Avenue that give priority to buses along the entire corridor (BRT Centre of Excellence et al. 2017).

Some Chinese cities have built elevated roads dedicated to BRT and separated it from other surface transportation, which can compensate for congested narrow roads in downtown areas (Bian and Ding 2012). Elevated roads can, however, be costly to build. Xiamen BRT from Xiamen Island and Erhuan Lu corridor in Chengdu obtained full intersection treatment scores in the ITDP evaluation because of their elevated busways, which do not allow turns across the BRT lane. Some studies, however, have pointed out the inflexibility of Xiamen's elevated lanes. Xiamen BRT, for example, has only two bus lanes (one per direction), with no emergency or passing lanes. This can cause long delays if BRT buses break down and need emergency rescue vehicles (Bian and Ding 2012). Elevated lanes or grade-separated junctions need to be carefully considered, along with the urban context and design needs, to attempt to mitigate potential urban impacts.

Intersection treatment is important not only for improving bus operations but also for providing pedestrians with safe access. Research has shown that removal of left turns at intersections has the potential to improve safety, both in respect to collision frequency and severity. For example, injury and fatal crashes can decrease by approximately 22 percent and vehicle collisions can be reduced by about 26 percent (Duduta et al. 2014).

International experiences using TSP with either regular or BRT buses include the following:

- In Los Angeles, employing TSP resulted in a 25 percent reduction in overall bus travel times (Tann and Hinebaugh 2009).
- In Phoenix, implementation of TSP at seven intersections helped reduce bus signal delay by 16 percent (Tann and Hinebaugh 2009).
- Zuidtangent in Amsterdam, Stombuss in Göteborg, and Brisbane Busway are examples of BRT systems that have implemented dynamic signal priority in all of their BRT corridors (BRT Centre of Excellence et al. 2017).

MULTICORRIDOR NETWORKS

A BRT network, according to Cervero (2013), should imitate and complement the spatial coverage of other transport modes and facilities, such as a metro. One of the advantages of BRT is its flexibility to adapt to changing demand and expand as a network. A BRT system can cover an entire metropolitan area and expand travel options for passengers since it allows buses to circulate in different corridors and create more bus routes, thereby reducing the number of transfers that users must make to get to their destination.

In China, the process of achieving multicorridor networks has been rather slow. So far, only six Chinese cities have built BRT systems with more than one corridor, and BRT lines in those cities are not necessarily interconnected (BRT Centre of Excellence et al. 2017). As a positive example, Jinan's BRT system, which opened in April 2008, serves 4 corridors divided into 6 operating routes with 46 stations. The system allows free transfers between BRT lines at transfer stations (Jiang et al. 2012).

While ideally BRT corridors should form a network, BRT designers and planners should also consider the existing urban context and the specific role that BRT should play in the city's transport system. Beijing BRT, for instance,

has four independent BRT lines that are not connected to each other, partly because of the unique urban context of old Beijing with the Forbidden City located in the center. Based on the passenger demand, other connections—for example, through one of the ring roads—could still provide BRT network connectivity.

Examples from international experiences include the following:

- TransJakarta in Jakarta, Indonesia, has 12 corridors all connected with each other. This is the most extensive BRT system in the world, and, according to the Jakarta Transportation Masterplan, the city has plans to build additional corridors (Rini 2014).
- Transmilenio in Bogotá, Colombia, is a very high-capacity BRT with a peak load of 44,000 pphpd. The system has 11 connected corridors, with multicorridor services being provided (Centre of Excellence et al. 2017).

While our research only finds a significant negative difference for Chinese BRT systems in the multicorridor network indicator, there is no statistical significance for the integration with other public transport subcategory. Still, city planners and decision makers who prioritize passengers to deliver a quality transport service must consider multimodal, multicorridor integration of transport modes—including bicycling, which is especially relevant in a country like China with an important bike history and culture—in order to be able to serve the demand, which varies across different times and geographical areas.

EXPRESS OR LIMITED-STOP SERVICES

Express or limited-stop services are important for achieving high-capacity, high-speed BRT systems. Unlike regular local services, which stop at every station, BRT express services gather passengers with similar origins and destinations into one route, skip those stops that the users do not require, and drop them off at the other end of the corridor. Similarly, BRT limited-stop services stop only at some stations, skipping stations with lower demand. Both BRT express and limited-stop services reduce the total number of interruptions at the stations and thus can increase the average operating speed of bus services, thereby saving passenger travel time (Table 4). High-demand BRT systems often have passing lanes (discussed below under "Passing lanes at stations") that can facilitate express services.

Table 4 | **Operating Speeds in Bus Rapid Transit Systems with and without Express Services**

TYPE OF BRT TRANSIT MODE	OPERATING SPEED (KM/HR)
BRT on urban arterials and no express service	18–28
BRT on suburban arterials with predominantly express service	28–35
BRT on expressway (with no intersections and no express service)	40+

Source: Adapted from Carrigan et al. (2013).

Express and limited-stop services are probably the only tool in high-demand systems that allows the capacity of a BRT system to exceed 20,000 pphpd (Larraín et al. 2016). But they deliver benefits only when demand for transport in the corridor reaches a certain threshold or presents a specific demand configuration (Larraín et al. 2016), and therefore they might not be suitable for cities with low passenger demand.

For example, in 2010, Guangzhou BRT introduced operational adjustments, such as express routes and 18-meter BRT buses, in order to deal with delays and slow morning peak operational speeds due to very high demand (Fjellstrom 2010). A newer BRT system, the Yichang BRT, also offers limited and express services (ITDP 2016b). Depending on the passenger demand level, other Chinese cities can also follow the examples set by Guangzhou and Yichang, which represent good models for large and medium-sized cities, respectively (ITDP 2015).

International experiences include the following:

- The Boqueirão corridor in Curitiba, Brazil, has a daily demand of 92,000 passengers, and its express service has an operating commercial speed of approximately 28 km/hr (BRT Centre of Excellence et al. 2017).
- The TransOeste corridor in Rio de Janeiro, which runs very long trips and experiences an imbalanced demand along the corridor, is another example that has express service. With an average demand of 240,000 passengers per day, the corridor has an operation speed of approximately 50 km/hr, which is about 20 km/hr higher than the rest of the BRT routes (BRT Centre of Excellence et al. 2017).

DEMAND PROFILE

According to Fjellstrom (2010), the first BRT corridor in a city should serve congested and high-demand locations in order to have an immediate impact in terms of travel time savings for a large number of users. In addition, high-quality BRT systems should be located along these high-demand corridors. By high-quality BRT, we mean that the BRT infrastructure has design characteristics such as intersection treatments that can facilitate high-speed, high-capacity BRT services.

In China, Guangzhou BRT on Zhongshan Avenue has been the exemplary BRT; its high-quality corridor exists along a high-demand corridor providing the greatest time savings for the passengers. This is important because poorly designed BRT systems will not deliver the required capacity and the desired quality, and they can therefore erode support from users and the public or hinder authorities from expanding the service.

Dedicating spaces exclusively for public transport in congested areas also has the potential to provoke resistance from nonusers. For example, in 2012, the dedicated lanes in Chongqing's BRT system were vehemently criticized by private car drivers who perceived that the system was causing congestion. Later, the Chongqing government started allowing other buses in the dedicated BRT lanes, which worsened the service quality and ultimately led to the first-ever demolition of a BRT system in China (Zeng 2013). Similarly, in Guangzhou, locals playfully termed BRT as “Bu Rang Tong” or “Not allowing (cars) to pass through” (Zeng 2013). This is partly due to the motorists not understanding the total volume of traffic being carried by the BRT lane or the number of passengers transported by the system, instead merely observing the empty lanes restricted from use by private cars.

In 2016, the Guangzhou government began allowing mixed traffic in the city's signature BRT lanes during peak hours, reducing the speeds from about 20 km/hr to 16 km/hr. As the performance of the public transport degraded, the passenger throughput also dropped, to 20,800 pphpd in July 2016, compared to about 28,000 pphpd in previous years (Far East BRT 2016). These cases highlight the importance of both changing citizens' perception of BRT and of giving priority, in cities with high density, to travel modes that utilize road space most efficiently.

The issues of the allocation of public space to different transport modes are not unique to Chinese cities. One of the drawbacks of Bangkok BRT, for example, was that the corridor ran through a low-demand area in order to avoid right-of-way controversies (Wu and Pojani 2016). This defeats the purpose of BRT and can color people's perception of BRT as a marginally successful public transport mode. International experiences from Delhi, Ahmadabad, Mexico City, and Santiago also attest that shifting limited road resources away from personal cars and successfully deploying BRT systems will require compromise on the best use of available space (Jones 2017) from government institutions with strong political will (Paget-Seekins 2016). On the positive side, the ITDP (2016b) identifies the Gold-standard MOVE-Cristiano Machado BRT in Belo Horizonte, Brazil, as one of the very high-capacity corridors located in high-demand areas, including the city center.

PASSING LANES AT STATIONS

Overtaking or passing lanes are important design elements that can increase passenger carrying capacity. They are a necessary component of express or limited-stop services (discussed above under "Express or limited-stop services") in order to facilitate high-demand arrivals through high-frequency services, allowing BRT stations to simultaneously serve a large volume of buses without creating long lines of buses waiting to stop (Table 5).

Table 5 | **Peak Load Capacity for Bus Rapid Transit with and without Overtaking Lanes**

TYPE OF BRT TRANSIT MODE	PEAK LOAD CAPACITY (KM/HR)
BRT with single lane and no overtaking	Up to 13,000
BRT with overtaking lanes and multiple substops at stations	43,000–55,710

Source: Adapted from Carrigan et al. (2013).

Although passing lanes are more difficult to justify in systems that start at a low-demand level, they are a good investment in high-demand scenarios in which passenger trips are long and high capacity is required. Also, since passing lanes occupy more space for the corridor, they should be installed only in the vicinity of the BRT stations, avoiding construction between stations where possible. Due to its high demand, Guangzhou BRT, for example, is a

good candidate for passing lanes. Lanzhou is another city that has implemented passing lanes along its entire BRT corridor, while Urumqi and Xiamen also implemented the passing lanes in parts of their corridors (CATS 2016).

International highlights on implementing passing lanes for BRT include the following:

- The first international BRT to introduce passing lanes to increase its capacity was TransMilenio BRT in 2000 in Bogotá (ITDP 2014a).
- In Buenos Aires, the busy 9 de Julio BRT corridor uses public space effectively on one of the world's broadest urban arterials by utilizing passing lanes in order to increase capacity through the city center (ITDP 2016b).

STATION SETBACK FROM INTERSECTIONS

If a BRT station is too close to an intersection, buses can start forming lines during boarding/d disembarking or at traffic lights, which reduces operating speed—especially if the station lacks other important features, such as dedicated lanes and intersection treatments. If the station happens to be downstream of the junction, the line at the station could block the intersection (Herrera et al. 2016), damaging the quality of service to users and the system capacity.

In Chinese cities such as Changzhou, Jinan, Kunming, and Zhengzhou, BRT stations are located at intersections, which limits the number of buses able to line up at the station (Fjellstrom 2010). In Changzhou, even though the traffic flow is not very high, BRT stations located at the intersection result in lines blocking the intersection and pedestrian access (Chen 2016). Our suggested setback length from an intersection is one length of a BRT bus; most of the BRT systems in Chinese cities use a combination of regular 12-meter single-decker and 18-meter articulated vehicles (CATS 2016). The ITDP (2014a) recommends a greater setback distance, with minimum and ideal setback lengths of 26 meters and 40 meters, respectively.

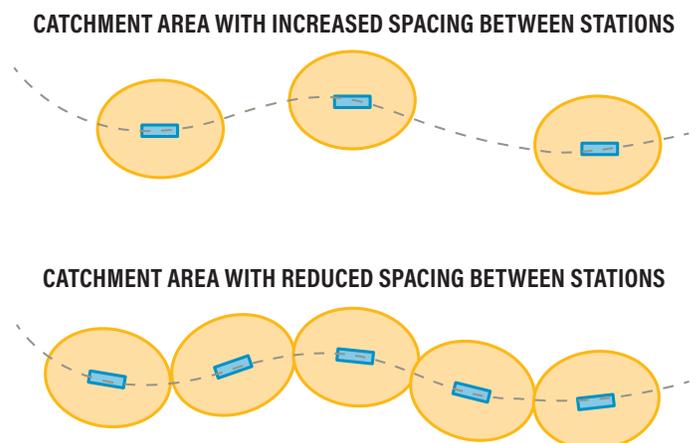
Worldwide, most cities have slowly adopted station setback: Janmarg in Ahmadabad (ITDP 2014a), TVM in Paris's eastern suburbs, Bangkok BRT in Bangkok, and TransMilenio in Bogotá are some examples of BRT systems in which the stations are not immediately adjacent to the intersection (Far East BRT 2017). In Delhi, however, BRT stations are located very close to the intersections, and this configuration, along with other design issues such as station sizing, contributes to bus bunching and congestion at intersections (Rizvi and Sclar 2014).

DISTANCE BETWEEN STATIONS

When BRT stations are far apart, although the vehicle operation speed increases and in-vehicle travel time for passengers decreases, people must walk longer distances to stations, effectively reducing the number of riders who can be served by each station. When BRT stations are close together, the bus speed will be reduced but the system will cover a larger catchment area, serving more customers and reducing the time spent walking to the station (see Figure 6). In addition, many passengers get to BRT stations by other transport modes (such as bicycles, buses, and taxis) instead of walking. For them, a long distance between stations may not be an issue.

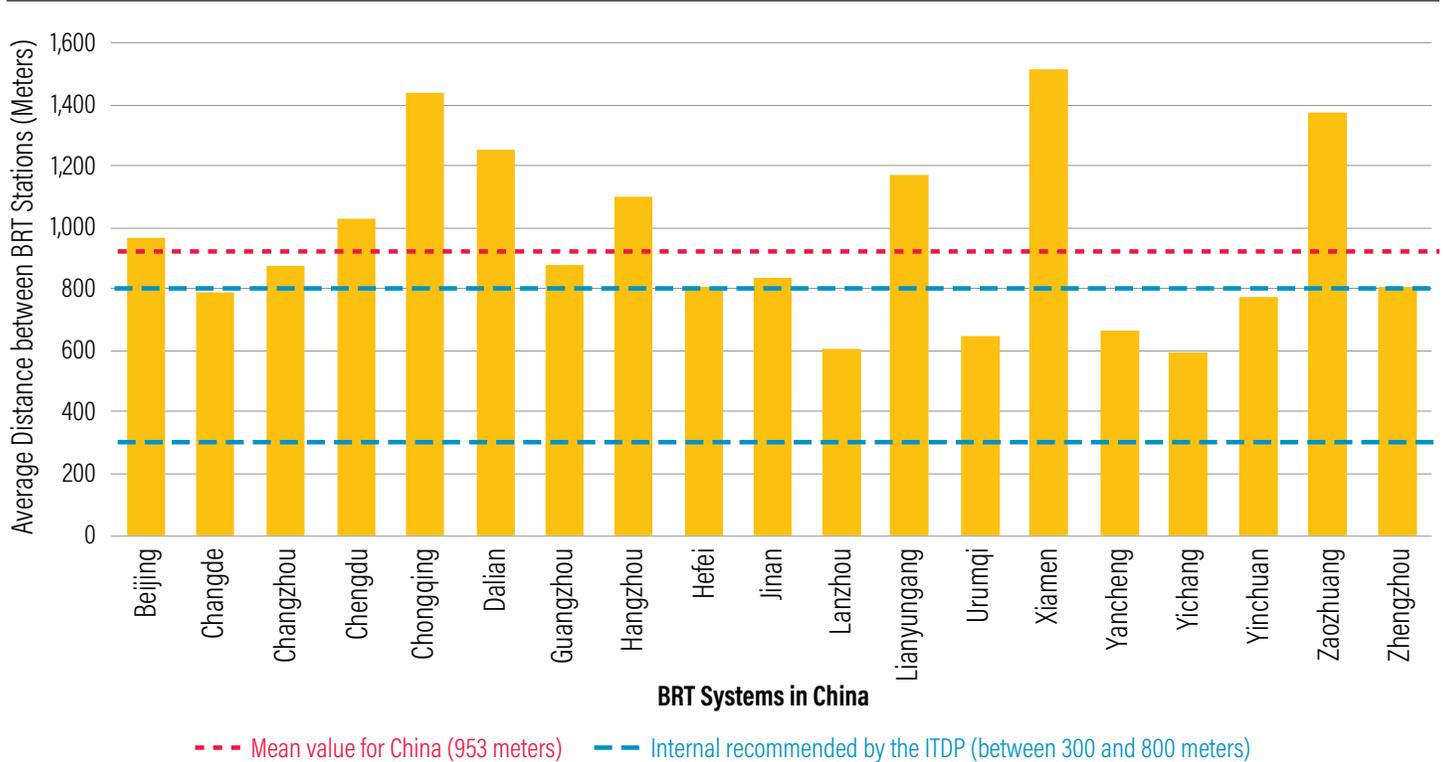
In general, station spacing will vary across a given corridor, as the corridor moves through central areas and less densely populated areas, in order to maximize access while maintaining speeds. According to the *BRT Standard*, the optimal distance between stations, in a uniformly built-up location, is approximately 450 meters (ITDP 2014a). BRT systems receive a full score if the average distance between stations is between 300 meters and 800 meters. Based on BRT Data (BRT Centre of Excellence et al. 2017), the mean value of the station spacing for BRT systems in 19 Chinese cities is 953 meters (Figure 7), while the average station spacing is between 600 and 700 meters for most bus priority systems in the world (Lindau et al. 2016). However, it is important to note that the station spacing highly depends on factors such as the corridor's urban configuration and population density gradient to be able to balance speed and coverage. Also, it is not unusual for BRT corridors connecting suburban to central areas to employ

Figure 6 | Catchment Areas with Different Station Spacing



Source: Vuchic 1981.

Figure 7 | Average Distance between Bus Rapid Transit Stations in China



Source: BRT Centre of Excellence et al. 2017.

station spacing of more than 1,500 meters (Lindau et al. 2016). Alternatively, if overtaking lanes are deployed along with express or limited-stop services, the distance between stations could be shortened for a wider coverage while still achieving high speed because not all BRT services stop at every station.

International highlights regarding station spacing include the following:

- In Las Vegas, the average speed of the Metropolitan Area Express (MAX) BRT system is approximately 25 percent higher than average speeds of local transit, primarily as a result of increased station spacing (Kim et al. 2005). The BRT has 22 stations with an average spacing of about 1 mile (1.6 km), which works well in a city with relatively low population density along the corridor.
- Istanbul BRT achieves commercial speeds up to 40 km/hr in a fully segregated facility with long station spacing of 1.2 kilometers (Yazici et al. 2013).

Best Practice Indicators

MINIMIZING BUS EMISSIONS

Minimizing BRT emissions is especially critical in areas near a stop (for example, an intersection) or at stations. This is because emission concentration is higher at BRT stations than in other parts of the BRT corridor (Chen et al. 2012), and passenger boarding and disembarking takes place at these emission hot spots.

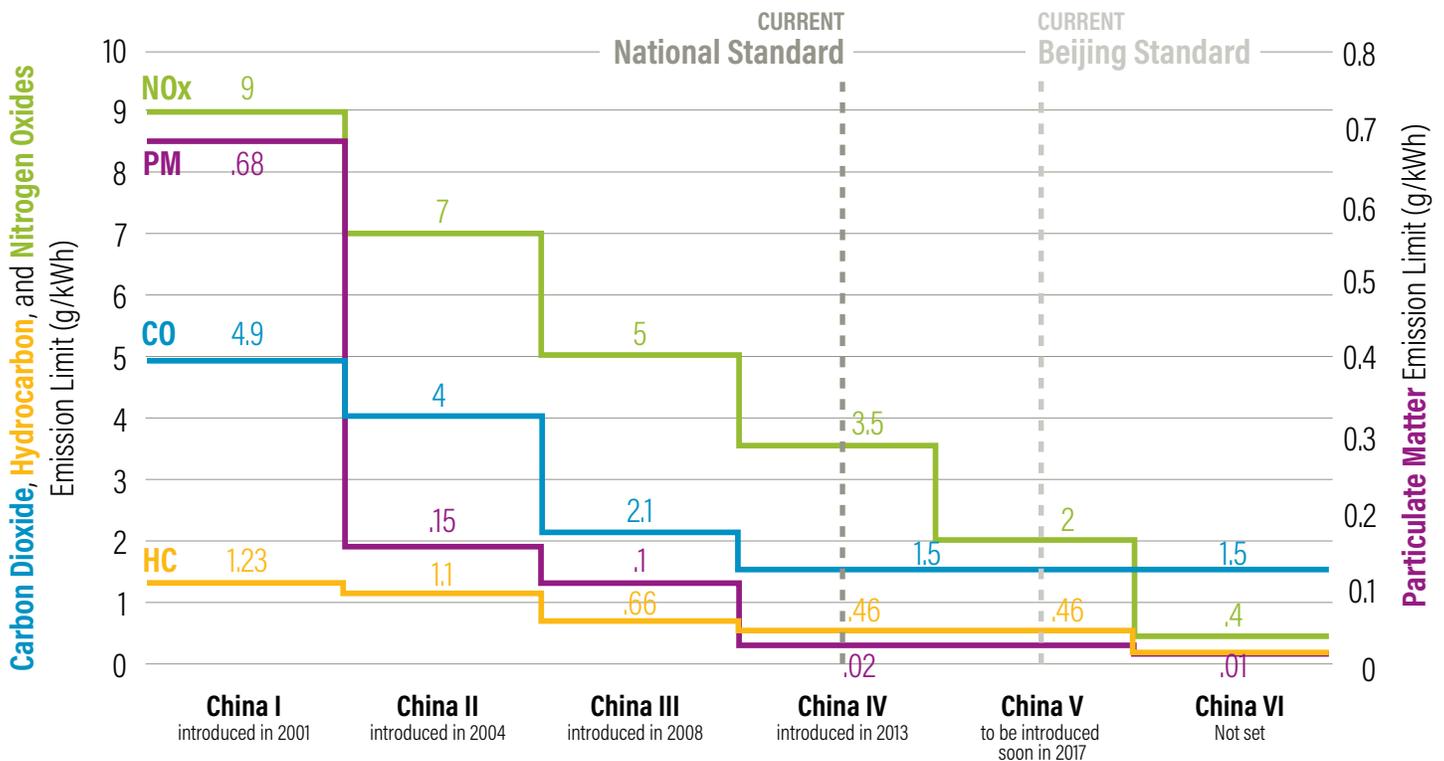
There are several ways BRT systems can minimize emissions: ideally, by averting current public transit users from switching to private vehicles and attracting passengers from private vehicles, thereby reducing the overall vehicle kilometers traveled; by providing smoother driving cycles with reduced disruptions and lower idling times via congestion reduction—which can be achieved using exclusive bus lanes along with intersection treatments; and by employing more efficient vehicle technologies (Cooper et al. 2012). This subsection, in accordance with the *BRT Standard*, focuses on the third option.

Chinese BRT buses most commonly use diesel and usually meet a minimum of Euro III, a commonly used European standard (Deng et al. 2013). There is an opportunity for BRT systems in China to shift toward more stringent emission standards, such as Euro VI or US 2010. Often, government agencies set the limits for tailpipe emissions for local air pollutants such as particulate matter or nitrogen oxides, and stricter standards could be achieved via national and citywide mandates.

In fact, China has already been introducing rigorous standards to address China’s pollution problems, as illustrated in Figure 8. For instance, countrywide implementation of China V, which is based on Euro V, for all vehicles is scheduled for 2017. In addition, China VI, which can be considered as an equivalent of Euro VI and is thus by far the strictest emission standard for heavy-duty vehicles, was to be enforced by the end of 2017 in Beijing, a leading city for vehicle emission standards implementation (DieselNet 2016).

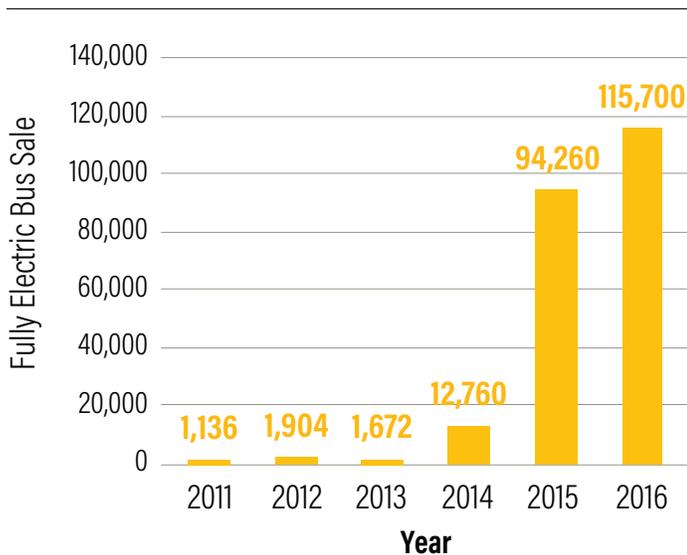
As part of the integral strategy to reduce national greenhouse gas and air pollution, the MOT (2015), in *Implementation Opinions Concerning Hastening the Promotion and Usage of New Energy Vehicles within the Transportation Sector*,³ set the goal of deploying at least 200,000 new energy⁴ public buses by the year 2020 (*Beijing Daily* 2015). In fact, by the end of 2015, China had 170,000 of the 173,000 electric and hybrid buses⁵—that is, 98 percent—existing in the world (Ayre 2017). Figure 9 shows the astonishing sale of fully electric buses in China in recent years. Cities like Nanjing and Shenzhen are also already deploying hundreds of zero-emission buses (People.cn 2014). However, the process needs to further trickle down across all BRT systems at a larger scale. Recently, city governments like that of Urumqi announced the deployment of new energy vehicles for all new 12-meter BRT buses (Urumqi Government 2017), and BRT systems in China are well positioned to embrace and incorporate these new technology buses.

Figure 8 | Evolution of Vehicle Emission Standards in China, 2001-17



Source: Graycar 2016.

Figure 9 | Annual Sales of 100% Electric (or Battery Electric) Buses in China, 2011-16



Source: Ayre 2017.

PROVIDING PEDESTRIAN ACCESS

Safe and high-quality pedestrian environments along the corridor—especially near the stations—are important for BRT. Due to lower traffic volume, pedestrians often perceive BRT lanes as safer compared to traditional traffic lanes (Duduta et al. 2012). In other words, pedestrian accessibility and safety are two sides of the same coin.

The main consideration for the design of pedestrian access is foreseeing all possible movements of pedestrians to and from the BRT station (Duduta et al. 2014). Open stations with low platforms can encourage dangerous behaviors such as midblock crossing, whereas closed stations (for example, those that have guardrails installed along the station pathways) with high platforms can decrease pedestrians’ risky movements. Also, dedicated lanes, especially near BRT stations, may need physical separations such as fences for safety. Other approaches to improve pedestrian access include providing signalized pedestrian crosswalks or at-grade crossings and pedestrian bridges or underpasses (Duduta et al. 2014).

Internationally, a case study in Porto Alegre, Brazil, shows a higher incidence of pedestrian crashes at busway stations than other locations, after taking into account the differences in traffic and pedestrian volumes and street design (Diógenes and Lindau 2010). Employing crash frequency models for Latin American BRT corridors,

Duduta et al. (2012) found that pedestrian refuge islands in the crossing center could provide better safety. At the same time, it is important to ensure that pedestrians are not stranded on narrow medians and refuge islands as a result of station overcrowding.

While there are trade-offs between improving pedestrian safety and operational performance, the negative impacts on key parameters such as commercial speed and travel times are relatively small (Duduta and Lindau 2016). That is, good design can help balance safety requirements while maintaining quality BRT services.

ENSURING UNIVERSAL ACCESS

BRT stations need to be accessible and convenient for all users, including passengers with special needs such as seniors, people with visual impairment, and people in wheelchairs.

BRT systems such as that in Xiamen provide limited access for passengers with wheelchairs, as there are many steps of stairs involved to access the station. Similarly, while Beijing BRT stations provide safe access by having pedestrian bridges and underpasses, many of them do not have lifts or ramps, which makes it difficult for disabled people, cyclists, pregnant women, and other special-needs passengers to access the BRT systems. Even when systems use low-floor buses or provide level-boarding platforms, customers with wheelchairs may still have difficulties accessing the system, and thus many BRT stations in China offer aides for passengers with disabilities (Deng et al. 2013).

International examples of BRT systems committed to universal access can be found in Ahmadabad and Indore in India. To provide more accessible stations, the designers of Janmarg BRT in Ahmadabad consulted with the Blind People’s Association (Rao and Shah 2012). The stations also facilitate level boarding and provide signalized pedestrian crosswalks (Kadri 2010). In both Indian cities, BRT stations are lauded because they are more accessible to customers with physical and visual needs than other public transport modes (Rao and Shah 2012). Similarly, for Metrobús Line 5 in Mexico City, which opened in 2013, a government social agency served as the coordinator for various groups of passengers with different accessibility needs, and each group evaluated the accessibility features of the BRT system (UN 2016). These examples highlight the need for effective user participation that can help translate and resolve passenger concerns.

6. CONCLUSION

Chinese cities are growing very rapidly, and the number of individual motorized vehicles is rising, with negative impacts on air pollution, congestion, and traffic fatalities. At the same time, demand for transit services is increasing. Chinese leaders have recognized public transportation as a key element for addressing all of these issues and helping the national government achieve its transport and climate change mitigation goals.

China has set a goal of expanding its BRT networks by about 2,000 kilometers by 2030. To get the most value out of its massive investment in these systems, it needs to ensure that its designs reflect international best practice. Doing so is critical because design features determine performance, systems are difficult to retrofit after they have been built, and poor-quality service can dissuade Chinese passengers from using BRT and erode public support for BRT expansion.

To guide planners as they prepare to expand China's BRT, this working paper benchmarks China's BRT systems against international standards. It identifies 11 design indicators on which Chinese systems score significantly lower than international counterparts and makes recommendations for improving them:

- Improve intersections, simplifying movements and providing traffic signal priority when appropriate.
- Plan multicorridor BRT networks to increase coverage, provide more options for users, and reduce the need for transfers by allowing buses to connect between corridors.
- Promote multimodal integration (e.g., integration between BRT and biking, which can cover the first and last mile to a BRT corridor).
- Add express, limited-stop, and local services, which increase average operating speeds and reduce travel times.

- Create high-quality BRT infrastructure (such as fully dedicated bus lanes) in segments with the highest demand.
- Provide passing lanes at stations to increase capacity, facilitate express services, and prevent bus bunching at stations.
- Set stations far enough back from intersections that at least one bus can line up, in order to increase the number of buses stations can serve at once.
- Balance coverage and speed by spacing stations optimally.
- Adopt cleaner vehicles, including electric buses, in order to reduce bus emissions.
- Improve pedestrian access to stations in order to improve safety of passengers and integrate BRT with the surrounding environment.
- Ensure that all passengers, including passengers with special needs, can access and use stations and vehicles.

This working paper creates a framework for an in-depth report that contextualizes and addresses BRT systems in China more broadly, possibly in terms of financial and institutional opportunities and challenges. Future research should explore the underlying policy issues that have caused Chinese cities to forgo key design characteristics that enable high-speed and high-capacity throughput, examine the relationship between design and performance, and study the effects of BRT design on infrastructure and operating costs.

APPENDIX

The *BRT Standard* Scorecard (2013 edition)

CATEGORY	SUBCATEGORY	MAX SCORE
BRT basics	■ Busway alignment	7
	■ Dedicated right-of-way	7
	■ Off-board fare collection	7
	■ Intersection treatments	6
	■ Platform-level boarding	6
Service planning	■ Multiple routes	4
	■ Peak frequency	3
	■ Off-peak frequency	2
	■ Express, limited, and local services	3
	■ Control center	3
	■ Located in top 10 corridors	2
	■ Hours of operation	2
	■ Demand profile	3
■ Multicorridor network	2	
Infrastructure	■ Passing lanes at stations	4
	■ Minimizing bus emissions	3
	■ Stations set back from intersections	3
	■ Center stations	2
	■ Pavement quality	2
Stations	■ Distance between stations	2
	■ Safe and comfortable stations	3
	■ Number of doors on bus	3
	■ Docking bays and substops	1
	■ Sliding doors in BRT stations	1
Communications	■ Branding	3
	■ Passenger information	2
Access and integration	■ Universal access	3
	■ Integration with other public transport	3
	■ Pedestrian access	3
	■ Secure bicycle parking	2
	■ Bicycle lanes	2
	■ Bicycle-sharing integration	1
Point deductions	■ Commercial speeds	-10
	■ Peak passengers per hour per direction below 1,000	-5
	■ Lack of enforcement of right-of-way	-5
	■ Significant gap between bus floor and station platform	-5
	■ Overcrowding	-3
	■ Poorly maintained busway, buses, stations, and technology systems	-8

Source: ITDP 2013.

The *BRT Standard* Scorecard (2014 edition)

CATEGORY	SUBCATEGORY	MAX SCORE
BRT basics	■ Dedicated right-of-way	8
	■ Busway alignment	8
	■ Off-board fare collection	8
	■ Intersection treatments	7
	■ Platform-level boarding	7
Service planning	■ Multiple routes	4
	■ Express, limited, and local services	3
	■ Control center	3
	■ Located in top 10 corridors	2
	■ Demand profile	3
	■ Hours of operation	2
	■ Multicorridor network	2
Infrastructure	■ Passing lanes at stations	4
	■ Minimizing bus emissions	3
	■ Stations set back from intersections	3
	■ Pavement quality	2
Stations	■ Distance between stations	2
	■ Safe and comfortable stations	3
	■ Number of doors on bus	3
	■ Docking bays and substops	1
	■ Sliding doors in BRT stations	1
Communications	■ Branding	3
	■ Passenger information	2
Access and integration	■ Universal access	3
	■ Integration with other public transport	3
	■ Pedestrian access	3
	■ Secure bicycle parking	2
	■ Bicycle-sharing integration	1
Point deductions	■ Commercial speeds	-10
	■ Peak passengers per hour per direction below 1,000	-5
	■ Lack of enforcement of right-of-way	-5
	■ Significant gap between bus floor and station platform	-5
	■ Overcrowding	-5
	■ Poorly maintained busway, buses, stations, and technology systems	-10
	■ Low peak frequency	-3
■ Low off-peak frequency	-2	

Source: ITDP 2014a.

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ENDNOTES

1. The latest data from Global BRT Data indicate that there are roughly 655 kilometers of bus priority and BRT systems in more than 20 Chinese cities (BRT Centre of Excellence et al. 2017). CATS counts the length of BRT routes, even when they provide part of their service outside the BRT corridor. Global BRT Data considers only the length of BRT infrastructure.
2. The ITDP evaluates BRT systems and recognizes high-quality systems with Bronze, Silver, or Gold rankings (with Gold being the highest).
3. Translation of “关于加快推进新能源汽车在交通运输行业推广应用的实施意见” by the US Department of Transportation (2016).
4. The Chinese term *new energy vehicle* includes hybrid electric, battery electric, fuel cell electric, and alternative fuel technologies (US Department of Transportation 2016).
5. The buses include battery electric vehicles, plug-in hybrid electric vehicles, and hybrid electric vehicles (Ayre 2017).

LIST OF ABBREVIATIONS

ANOVA	analysis of variance
BRT	bus rapid transit
CATS	China Academy of Transportation Sciences
ITDP	Institute for Transportation and Development Policy
MOC	Ministry of Construction
MOHURD	Ministry of Housing and Urban-Rural Development
MOT	Ministry of Transport
pphpd	passengers per hour per direction
TSP	transit signal priority

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