BRT and bus priority corridors including BHLS: a global overview

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Word count: 3,222 words text + 9 tables/figures x 250 words (each) = 5,472 words

Submission date: November 15th, 2014

ABSTRACT

Forty countries all over the world have implemented BRT (Bus Rapid Transit) and bus priority corridors including BHLS (Buses with High Level of Service). High quality and performance bus transit exists in 180 cities of emerging and developed economies. As result of massive investments, more than 150 cities around the world are planning new or expanding existing bus priority systems. We provide a global overview of BRT and bus priority schemes including BHLS on a corridor basis. We use a comprehensive database to develop comparative analyses ranging from more general aspects (e.g. geography, length and demand) to physical characteristics and performance in terms of demands and operating speeds. Every day, nearly 31 million passengers benefit from bus-based priority corridors, which cover a total length of 4,668 kilometers. There is strong prevalence of segregated over exclusive lanes, i.e. 80% as opposed to 6%. South America is not only where BRT was invented but also the source of ongoing innovation. After the turn of the millennium, the cumulative number of cities with bus corridors experienced exponential growth. Brazil is leading the statistics with 115 corridors totaling 828 km and benefiting 12M pass/day. There is need to expand the implementation of design features that have a strong impact on the performance of corridors in terms of capacity and speed. Successful examples are vital as inspiration for decision makers and planners, but design needs to be adaptive to local conditions and constraints; thus the importance of providing global overviews highlighting trends, features and performance analyses of bus priority transit on a corridor basis.

INTRODUCTION

BRT (Bus Rapid Transit) and bus priority corridors, including BHLS (Buses with High Level of Service) have expanded relatively fast over the last decade. They are now operating in many cities of emerging and developed economies around the world often offering a fast, safe, reliable and affordable transit alternative along urban roads suffering from ever growing traffic congestion. Globally, the ratio of private vehicles per 1,000 inhabitants, not including two-wheelers, increased 32% between 2004 and 2011 (*1*). Cars may be attractive to individuals but unrestricted accessibility to private traffic generates significant externalities to society that are inconsistent to the goal of making cities more sustainable.

Bus priorities improve transit performance and reduce travel time. Apart from retaining and attracting riders, high quality bus systems can also provide valuable environmental and public health benefits by: (i) diminishing the emission of greenhouse gases; (ii) reducing road fatalities, crashes and injuries; (iii) reducing local personal exposure to harmful air pollutants and; (iv) increasing physical activity for transit users (*2,3,4*).

In this paper we provide a global overview of bus priority schemes on a corridor basis. We use a comprehensive database to develop comparative analyses ranging from more general aspects (e.g. geography, length and demand) to physical characteristics and performance in terms of demands and operating speeds.

BUS PRIORITY DATABASE

BRT Data (*5*) is a database created and made available to the public on the internet since April 2012, with the purpose of publicizing the state-of-the-practice of corridor-based bus priority systems. Its ultimate goal is to influence in the design of future corridor projects by providing information on different attributes and indicators, including elements and aspects related to infrastructure, operational performance, fleet and road safety.

BRT Data is one of the projects developed by Across Latitudes and Cultures - Bus Rapid Transit (ALC-BRT), the center of excellence in BRT. By conducting applied research and outreach, ALC-BRT aims at improving the state-of-the-practice on the design, planning, financing, implementation, and operation of BRT systems. ALC-BRT is based in the Pontificia Universidad Católica de Chile and includes researchers and practitioners from EMBARQ, Universidade Técnica de Lisboa, Massachusetts Institute of Technology and the University of Sydney (*6*).

BRT Data contains information on corridors that prioritize bus operation, including:

- BRT (Bus Rapid Transit), a fast mass transport system that couples the quality of rails with the flexibility of bus systems (*7,8,9*);
- BHLS (Bus with High Level of Service), a more efficient system than conventional buses, offering more comfort to users than BRT systems (*10*);
- Bus corridors with segregated lanes, including different configurations that range from segregated median to curbside lanes indicated by horizontal markings.

BRT Data is not fully exhaustive but is being continuously updated. Currently, it gathers information on 116 attributes and indicators of 363 bus-based priority corridors located in 180 cities from 40 countries all over the world. Every day, nearly 31 million passengers use these corridors, which cover a total length of 4,668 kilometers. Figure 1 illustrates the data distribution of corridors per region of the globe where the size of the circles represents the daily demand.

South America is not only where BRT was invented (*11*), but also the source of ongoing innovation. Latin America and the Caribbean are home to 33% of the total cities with bus priority systems and 49% of the world´s corridors. Some 62% of the total global daily demand of passengers benefiting from bus corridors derives from this region. Some 20% of cities in the database are located in Asia that responds for around a quarter of the global demand. Europe has 28% of the cities in the database and 6% of the global demand.

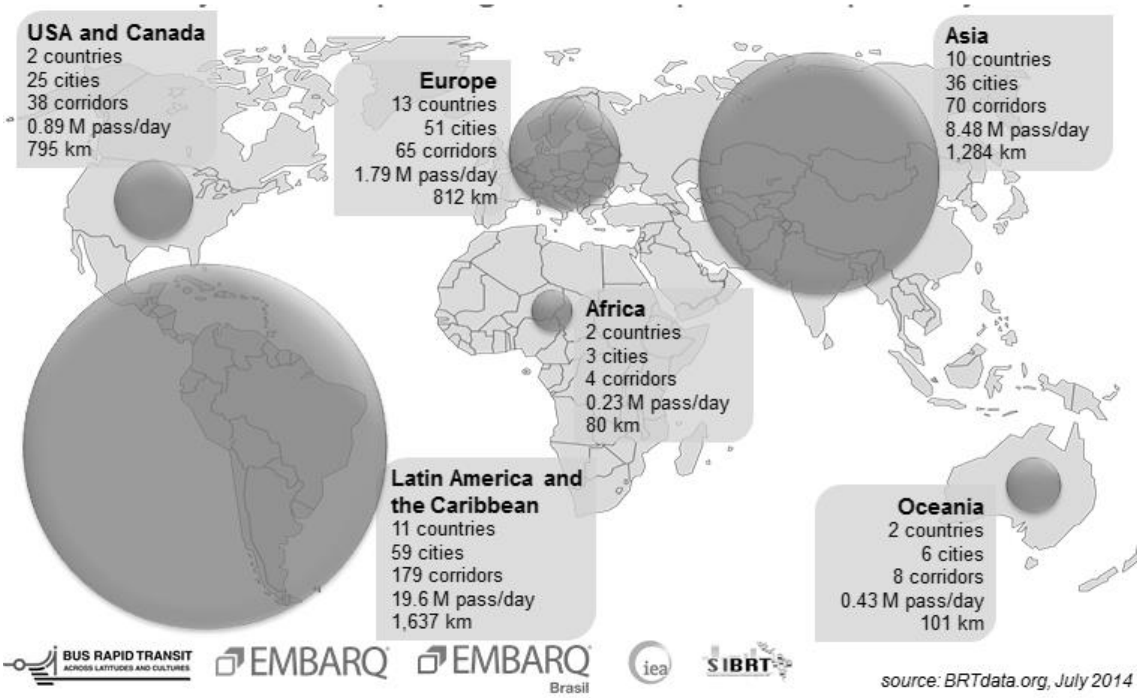

FIGURE 1 Global distribution of BRT and bus priority corridors.

From early 1970s, when the first bus corridors were built in the Americas, to 2000, when TransMilenio was inaugurated in Bogotá, the expansion of bus corridors was relatively modest. But after the turn of the millennium, the cumulative number of cities with bus corridors experienced exponential growth, as shown in Figure 2. It is expected that until 2019, 169 cities will be launching new or expanding existing bus priority systems adding 3,500 kilometers (*12*).

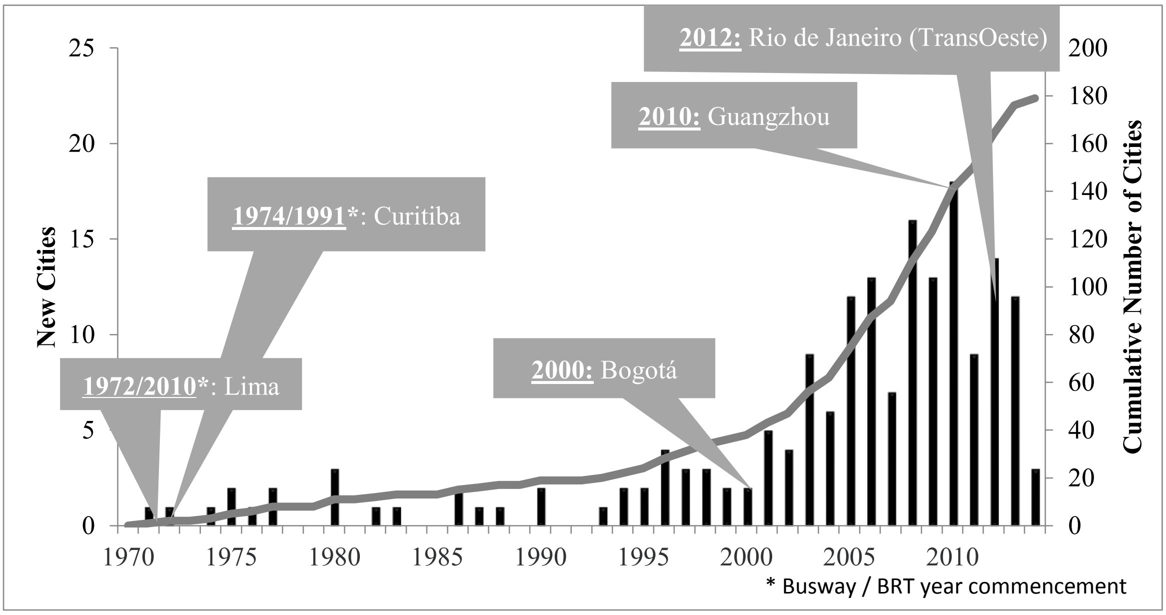

FIGURE 2 Growth of cities with bus priority systems.

COMPARING BRT AND BUS PRIORITY CORRIDORS

In this paper, our comparative analyses comprise three dimensions: (i) general aspects, distributing corridors according to geography, length, and demand; (ii) physical characteristics, grouping corridors in relation to design elements that impact bus speeds and reliability; and (iii) performance, focusing on demands and operating speeds.

General aspects

Figure 3 shows the incidence of different types of road infrastructure bus priority per total length of implemented corridors. Segregated lanes are physically separated (e.g. by paint, curbs or fences) from other traffic, allowing at-grade crossings for vehicles and pedestrians mostly at intersections (*13*). Exclusive lanes are physically separated facilities for bus travel at all times with no level crossing opportunities for pedestrian and other vehicles (*13*). Counterflow lanes are those where buses operate in the opposite direction of the rest of the traffic (*13, 14*). Mixed traffic extensions define segments of corridors where buses operate without any form of road priorization.

The easiness of implementation contributes to the strong prevalence of segregated over exclusive lanes, i.e. 80% as oposed to 6%. Counterflow lanes add to only 3% of the length of bus priority corridors. They are the most dangerous configuration for bus systems as many road users may not antecipate buses arriving from a counterflow direction (*14*). Mixed traffic extensions usually conform the segments to be upgraded once bus services between suburban terminals and the start of the priority corridors start to face disruption by other vehicles.

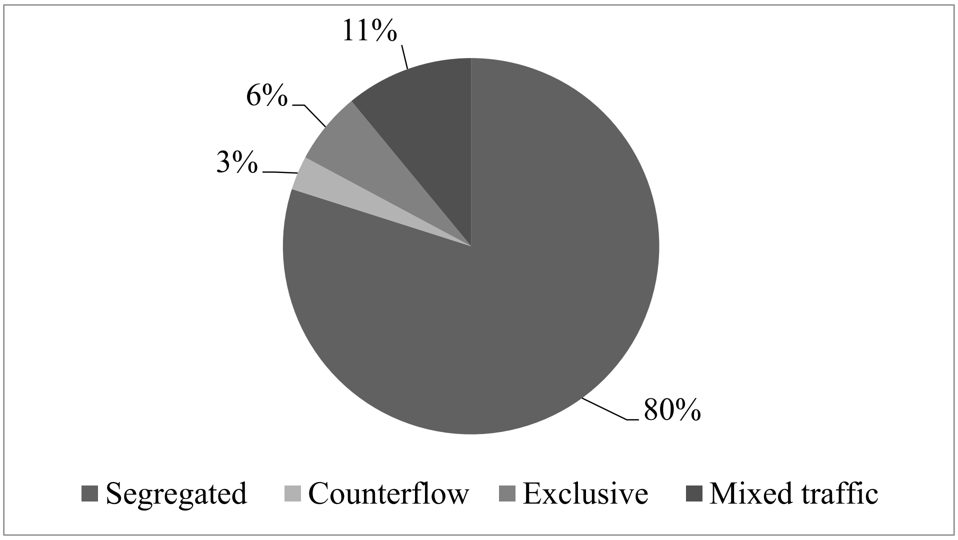

FIGURE 3 Incidence of different types of priority infrastructure.

Countrywide data in terms of cities, corridors, lengths and daily demands are shown in Table 1. Brazil, China, France and United States are the countries with the largest number of cities (from 33 down to 18) with corridors where bus transit benefits from any form of physical priority. In Europe, France and United Kingdom are the countries with the largest number of corridors, respectively 23 and 13. Chile and Indonesia, where bus priority exists only at their capital cities, present the largest average incidence of bus corridors per city (more than 12), a relevant proxy for indicating the existence of a city-wide bus priority network. It is important to mention that many cities in the developed countries have significant rail based transit networks, most of them implemented last century.

While China is one of the fastest growing BRT nations in the world, Mexico, Colombia and India also show noteworthy cases of expansion as result of national policies that foster the implementation of BRT corridors (*2*). United States, where private cars account for the great majority of urban trips, hosts the world´s third largest length of bus priority corridors with a total of 555 km. If emerging countries were to apply an effort of similar scale to the US in assigning road space for buses, there would be an even more impressive global presence of BRT and bus priority corridors including BHLS (*15*).

With almost 12 M passengers/day, Brazil is number one in terms of passengers benefiting from any form of bus priority corridor. It daily demand totals three times the equivalent figure for China. As a proxy for estimating the use of built infrastructure, the total nationwide daily demand, in terms of passenger volume using BRT and bus priority corridors, was divided by the respective country´s corridor length. Results presented in Table 1 indicate that systems operating in Argentina, Turkey, Brazil, Colombia, Iran, Peru and Taiwan exhibit the highest productivity, i.e. more than 13,000 daily passengers per kilometer of implemented BRT and bus priority corridors.

Physical characteristics

Some of the attributes registered in BRT Data have a stronger impact on the performance of the corridors in terms of transport capacity, operating speed and reliability (*16*). Figures 4 and 5 depict the incidence of these attributes and design elements: (i) traffic signal priority for buses; (ii) bus overtaking opportunities at stations and terminals; (iii) fare pre-payment to boarding; (iv) at-level boarding at stations and terminals; and (v) average distance between stations.

Traffic signal priority is key to increase operating speeds and to regulate headways along the route thus preventing bus bunching (*17*). But more than 75% of the corridors do not count with bus actuated traffic signals (Figure 4). Bus overtaking at stations and terminals not only provide greater transport capacity (*7*), but also enable the operation of a combination of express, accelerated, and local services. However, only 29% of the priority corridors allow overtaking along all (entire) or sections (part) of the corridor. Fare pre-payment and at-level boarding allow shorter standing times at stations (*18*) and increase capacity (*7*). The majority of the corridors do not have pre-payment (55%); 38% offer pre-payment along the entire corridor and 7% along part of the corridor. At-level boarding occurs in about 50% of the cases but depending on prevailing docking maneuvers, not always at-level boarding results in adequate gaps between platforms of buses and stations or terminals.

Distance between stations is crucial for the performance of any transit system. The longer the distance between consecutive stations, the higher the operating speeds (*16,19*) and the capacity of the corridor (*7*). The most frequent average distance between passenger stations lies within the 600 to 700 m range (Figure 5). The typical design of corridors connecting suburban to central areas along highways uses station spacing of over 1.5 km. Shorter distances are associated to corridors serving city centers and operated by multiple bus services.

1 **TABLE 1 BRT and Bus Priority Including BHLS by Country**

	number of cities	number of corridors	length (km)	daily demand (kpass/day)	corridors/ cities	km/ cities	daily demand (pass/day)/km
Brazil	33	115	827.9	11,766	3.5	25.1	14,212
China	18	32	567.9	3,978	1.8	31.6	7,005
United States	18	29	555.1	361	1.6	30.8	650
France	18	23	236.9	444	1.3	13.2	1,875
United Kingdom	13	13	158.6	162	1.0	12.2	1,024
Mexico	9	13	264.8	1,918	1.4	29.4	7,241
Canada	7	9	239.5	530	1.3	34.2	2,213
India	7	7	143.1	387	1.0	20.4	2,702
Colombia	6	15	201.5	2,868	2.5	33.6	14,237
Australia	5	7	89.5	407	1.4	17.9	4,549
Netherlands	5	6	137.9	108	1.2	27.6	783
Sweden	3	5	95.7	100	1.7	31.9	1,045
Germany	3	3	46.1	102	1.0	15.4	2,213
Iran	2	9	147.9	2,000	4.5	74.0	13,523
Ecuador	2	8	107.9	1,143	4.0	54.0	10,594
Argentina	2	7	48.1	970	3.5	24.1	20,166
Italy	2	5	42.8	23	2.5	21.4	537
South Africa	2	3	58.5	42	1.5	29.3	718
Taiwan	2	2	89.7	1,202	1.0	44.8	13,408
Japan	2	2	28.5	9	1.0	14.3	316
Venezuela	2	2	18.3	60	1.0	9.2	3,279
Chile	1	14	91.9	341	14.0	91.9	3,710
Indonesia	1	12	206.8	370	12.0	206.8	1,790
Israel	1	3	40.0	N/A	3.0	40.0	N/A
Belgium	1	3	6.0	N/A	3.0	6.0	N/A
Guatemala	1	2	35.0	245	2.0	35.0	7,000
Turkey	1	1	52.0	750	1.0	52.0	14,423
Republic of Korea	1	1	43.0	400	1.0	43.0	9,302
Pakistan	1	1	26.0	130	1.0	26.0	5,000
Peru	1	1	26.0	350	1.0	26.0	13,462
Nigeria	1	1	22.0	200	1.0	22.0	9,091
Thailand	1	1	15.3	10	1.0	15.3	654
Switzerland	1	1	11.0	14	1.0	11.0	1,273
Czech Republic	1	1	10.3	18	1.0	10.3	1,756
Panama	1	1	9.1	N/A	1.0	9.1	N/A
Ireland	1	1	8.4	34	1.0	8.4	4,048
Uruguay	1	1	6.3	25	1.0	6.3	3,968
New Zealand	1	1	6.2	23	1.0	6.2	3,694
Portugal	1	1	4.8	27	1.0	4.8	5,625
Spain	1	1	2.0	3	1.0	2.0	1,600

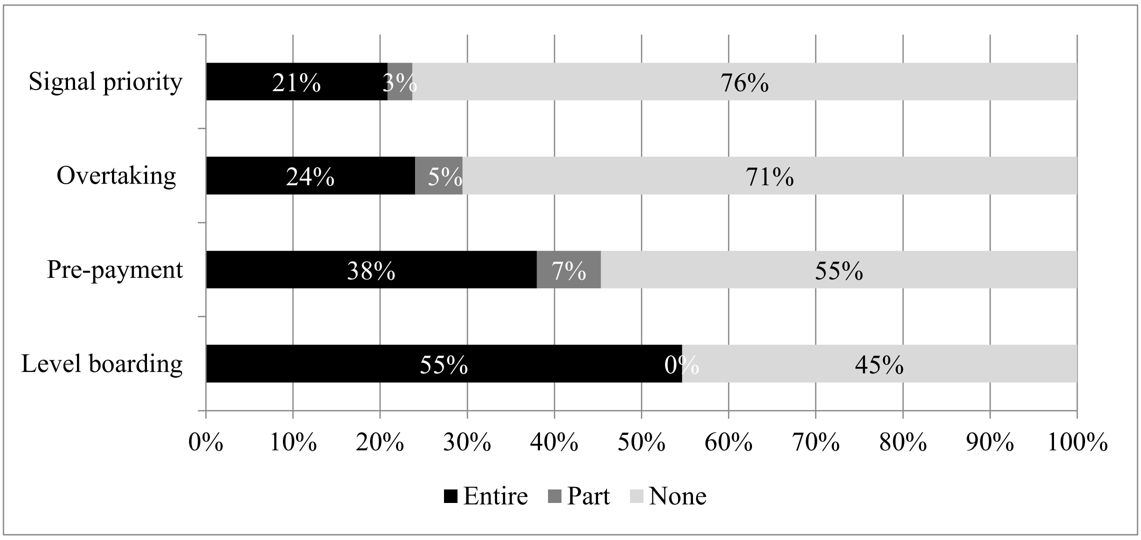

FIGURE 4 Incidence of design elements in priority corridors.

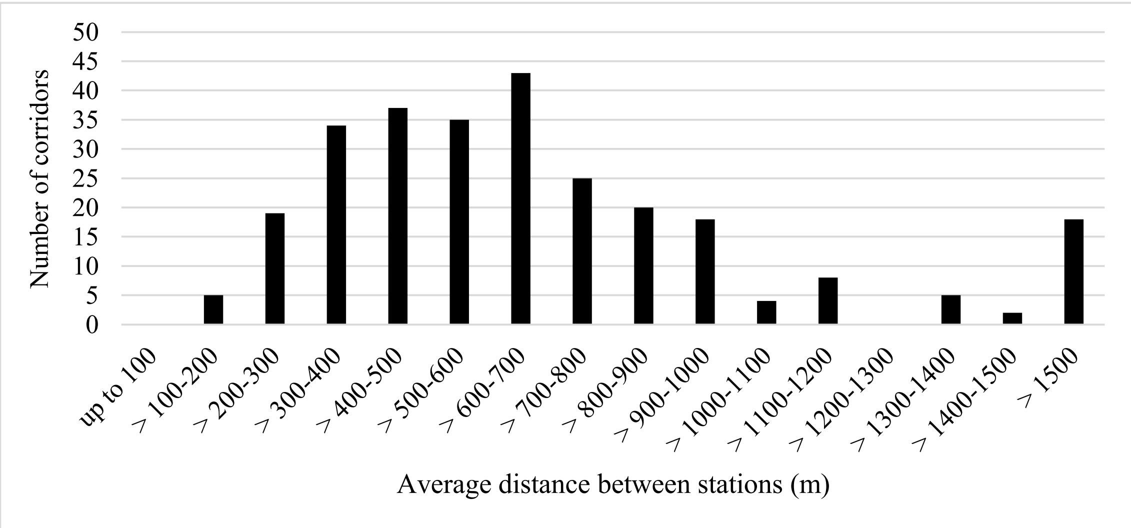

FIGURE 5 Average distance between stations.

Operating performance

The predominant average operating speed of the corridors is within the range >17.5 to 20 km/h as shown in Figure 6. Seventy per cent of the corridors has an operating speed from 15 to 25 km/h. As many bus priority lanes are located by the curb, interference with mixed traffic, such as right-turns, loading operations and residence parking, reduce the operating speeds. A few corridors have very high average operating speeds, such as the Australian busways in Adelaide (80 km/h) (*20)* and Brisbane (55 km/h) and the BHLS in Cambridge (60 km/h), benefiting from features like shuttle services, fully exclusive lanes, guided buses and traffic signal priorities.

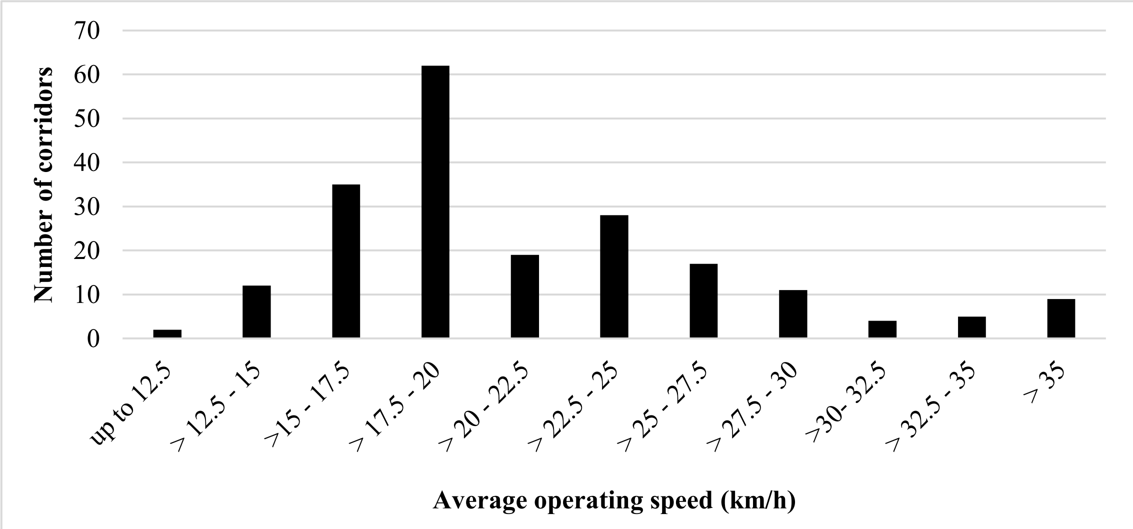

FIGURE 6 Operating speeds.

Figure 7 shows the maximum throughput, expressed in passengers per hour per direction, passing along the heaviest loaded section of the most demanded corridor on selected cities. The top three sections ranked include a four lane per direction bus corridor allowing the simultaneous operation of many different conventional bus lines locally branded as BRS (Bus Rapid Service) in Rio de Janeiro (*21),* the double lane per direction TransMilenio BRT corridor along Av. Caracas in Bogotá that was specially designed to accommodate heavy volumes of articulated and bi-articulated buses and the intercontinental single lane per direction BRT of Istanbul that uses central lanes of a highway road and crosses the Bosphorus bridge in mix traffic. Three bus priority corridors with completely distinct set of characteristics that fully explore the intrinsic flexibility of the bus concept in delivering high performance.

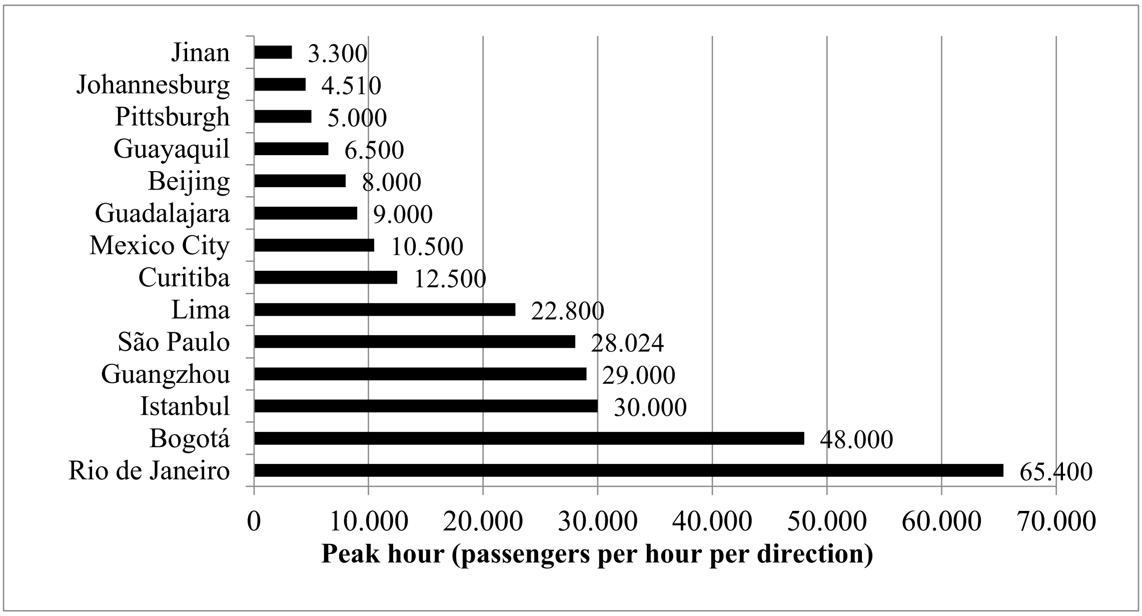

FIGURE 7 Maximum peak-hour per direction demand at the critical section of selected cities.

Figure 8 depicts the top 10 corridors in terms of daily demand and length. Only the Istanbul BRT corridor of Metrobüs stands as top on both. Heavy demanded (from 400 to 600 kpass/day) radial Brazilian corridors, used by many conventional bus lines to reach crowded city centers, populate the range up to 20 km long. Chinese bus corridors catering from low to very heavy demands - more than 800 kpass/day as in Guangzhou - populate the range from 20 to 35 km in length. The BRT of Av. Insurgentes and Av. Caracas, respectively in Mexico City and Bogotá, as well as bus priority corridors in Brazil, are also in this range. With daily demands of less than 150k passengers, and with the only exception of the TransOeste BRT corridor in Rio de Janeiro inaugurated in 2012, the American and European BHLS systems serving low density suburban areas predominate in the length range from 35 to 60 km.

São Paulo and Rio de Janeiro have three corridors each listed in the top 10. São Paulo has several bus priority corridors that total 162.8 km in length and serve 3.5 Mpass/day, but only Expresso Tiradentes (12 km; 60kpass/day) is a full BRT. In preparation for the Olympics 2016, Rio de Janeiro is implementing an entire network of bus priorities comprising 160 km of BRT and 178 km of BRS corridors.

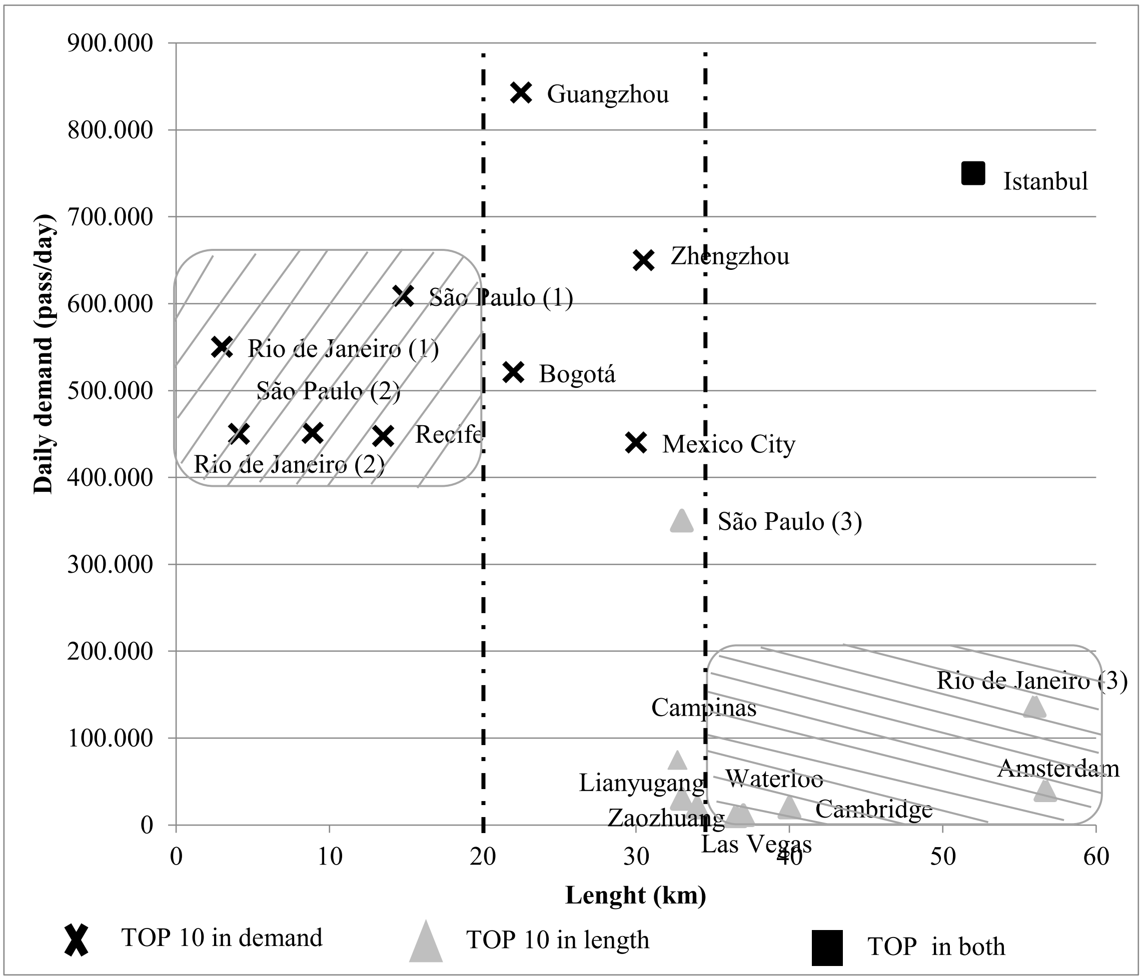

FIGURE 8 TOP 10 in daily demand and in length.

CONCLUSION

Today, 180 cities from 40 countries all over the world have implemented BRT and bus priority corridors including BHLS. The BRT concept has reached a tipping point, with national programs, massive new investment and significant expansion planned on the six global regions. More than 150 cities around the world are planning new or expanding existing bus priority systems until 2019, giving citizens access to safer, cleaner, more equitable transport and a higher overall quality of life. High quality and performance bus transit is now part of the portfolio initiatives towards a more sustainable urban mobility at the city level.

Many innovations in bus priority came from the congested cities in the emerging world where big challenges include the need to move high demands, and thus explore the capacity limits of surface space as in Rio de Janeiro and Bogotá. Nonetheless, there is the need to expand the implementation of design features that have a strong impact on the performance of corridors in terms of capacity, speed and reliability. Currently less than 25% of the corridors has signal priority and overtaking lanes and only 50% has at level boarding.

Bus based solutions are flexible; there is no unique set of characteristics that define an optimum. Successful examples of BRT and bus priority corridors including BHLS are vital as inspiration, but design needs to be adaptive to local conditions and constraints. Thus the importance of providing global overviews highlighting trends, features and performance analyses of bus priority transit on a corridor basis.

ACKNOWLEDGMENTS

The authors acknowledge the support of CNPq, EMBARQ Brasil and ALC-BRT, the Center of Excellence for BRT.

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