Bus Rapid Transit In India- A Compendium Report

SUPREME AUDIT INSTITUTION OF INDIA
लोकहितार्थ सत्यनिष्ठा
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This Research Paper is a part of our endeavor to improving accountability and inculcating professional excellence in the areas of environment and sustainable development. We have initiated from 2022 an Occasional Research Paper Series featuring different emerging areas of environment and sustainable development. This paper on **"Bus Rapid Transit in India- A Compendium Report"** forms a part of this Occasional Research Paper Series from International Centre for Environment Audit Sustainable Development, Jaipur, under the Comptroller and Auditor General of India.

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- FOREWORD-

Over the past decade, cities across India have commenced an active re-imagining of bus transit, most commonly now conceptualized as the Bus-Rapid-Transit, or the BRT. The concept of having buses ply in the centre of the road, on dedicated bus-only lanes, has gradually melded into our urban transport systems with a tenacious aim of mobilizing people rather than cars. Sustainable public transport modes like the Bus Rapid Transit (BRT) and Mass Rapid Transit (MRT) systems have been known to reduce congestion and pollution in cities and improve the quality of life. In a populous country like India, where overpopulation is a major problem, encouraging public transportation is the need of hour in order to conserve fuel resources. There is also a great need to provide clean, efficient, affordable, effective and safe public transportation system and to achieve this Bus Rapid Transit System (BRTS) could be one of the solutions.

The main goal of BRTS is to provide safe, convenient and timely public transport in urban areas for the common man and to make the streets of cities congestion free. The increasing need for urban mass transit mobility is now being addressed by various cities in India, following the best practices in the world.

The Government of India implemented Bus Rapid Transit System (BRTS) in various metro cities in India. The start of the BRT chapter in India can be traced to the announcement of the National Urban Transport Policy in 2006 by the Government of India. Between 2008 and 2015, Bus Rapid Transit (BRT) has increasingly become an attractive urban transit alternative in many developing cities due to its cost-effective and flexible implementation. However, some bottlenecks remain due to which the pace of development has been slower than the demand. This in turn has led to congestion and air pollution. At this crucial juncture where countries strive to contain their carbon footprint through innovative solutions, the core issues can simply be solved with a particular focus on mass transportation systems like BRT and MRT.

As a part of our newly initiated Occasional Research Paper Series and in the context of the challenges of BRT development in Indian Cities, this Occasional Research Paper of iCED seems to identify the pioneering strategies to support BRT implementation in Indian cities. The aim is to provide a sound database to planners and decision makers involved with BRT system implementation in India, as this paper contains inter-alia critical information about the:

- Various Indian cities that adopted BRT and their configuration
- BRT standards and the design guidelines from the Indian Roads Congress (IRC)
- The challenges Indian BRT is facing and possible measures

This report also contains information on pioneers in Global BRT systems for many years and some best practices that can be adopted for a successful BRT.

I would like to appreciate the efforts of the author Dr. Harsha, Research Associate at the iCED Jaipur, in bringing out the information to its current form. I sincerely hope that this Paper would help auditors to gain insight of BRT systems in India and also help to plan audits.

14 July, 2022
Jaipur

(Sayantani Jafa)
Additional Deputy CAG & Director General, iCED

MESSAGE FROM THE DIRECTOR

The dependency on fossil fuels and increased personal transport usage led to increased pollution and congested cities. While many solutions exist to overcome these issues, public transportation's advantage is reduced congestion. One of the well-known public transportation modes is the Bus Rapid Transit (BRT). Its ability to carry more passengers, lower development costs, less polluting at the per capita level and reduce city congestion makes it an attractive mode of transport. Like many cities globally, the congestion levels in Indian cities are also rising. The average kilometres travelled and time spent commuting between places has increased over the years, making transportation unsustainable in the long run. Therefore, sustainable transport modes such as BRT play a crucial role in addressing those challenges.

Latin American countries and China are considered pioneers in the BRT system and have some of the world's best BRT systems. India is relatively new to the BRT systems. Some cities in India have adopted the BRT, and the number is gradually increasing. Major concerns, such as public opposition due to reduced road space and accidents, lack of funding, and inefficient infrastructure and planning, led to Indian BRT not achieving the desired targets. However, it is opined that the BRT in India has the potential to be one of the leading sustainable transportation systems, provided the crucial issues are addressed.

As auditors, our esteemed duty is to identify these critical issues for the system to run successfully and seamlessly. In this regard, we at iCED bring forth a compendium report on BRT in India. This report consists of the BRT trends at the national and global levels. The Indian policies for BRT, BRT standards and the IRC guidelines for designing BRT are also presented. Despite continued efforts from the local and state governments, the reasons for Indian BRT not achieving desired results are discussed, and the possible ways to solve those issues are presented.

The efforts of the report author Dr. Harsha, Research Associate at iCED, are greatly acknowledged. As this report is compiled from multiple sources, I hope it finds its usefulness in providing crucial knowledge support to auditors.

(Pushkar Kumar)

Director (Training & Research), iCED

ABSTRACT

The Bus Rapid Transit system (BRTs), a road-based mass transportation system, has become increasingly popular in recent years due to its ability to carry large passengers with less cost and faster travel times, leading to reduced congestion and pollution. The Latin American countries are considered pioneers in the BRT system and have some of the world's best BRT systems which attained the Gold Standard. Along the lines of Latin American countries, China also extensively built BRT from the early 2000s and is currently leading the BRT system.

In India, BRT is operating in 10 cities with 3 projects in the pipeline. The first BRT was tested in Pune, and Ahmedabad is the first high-end BRT leading the BRT in India with the largest daily passenger demand. Compared to Latin American countries and China, BRT in India still has a scope to grow significantly. However, issues such as public opposition due to reduced road space and accidents, lack of funding, inefficient infrastructure and planning have led to Indian BRTs not achieving the desired targets. Although cities such as Ahmedabad claim to be the best BRT in India, it has been consistently running in losses, and the contrary is observed with Indore BRT, which is running in profits.

This study is a compilation of BRT systems worldwide with a primary focus on Indian BRT. The global and Indian BRT trends are analysed and presented with emphasis on some Indian cities. The Indian policies for BRT, BRT standards and guidelines for designing BRT are also introduced. Further, the reasons for the success/failure of Indian BRT are discussed, and the recommendations are presented.

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GLOSSARY

BRT	–	Bus Rapid Transit
CO_2	–	Carbon dioxide
GHG	–	Greenhouse Gas
GOI	–	Government of India
IETT	–	Istanbul Electricity, Tramway and Tunnel Survey
ITDP	–	Institute for Transportation and Development Policy
JnNURM	–	Jawaharlal Nehru National Urban Renewal Missions
MRT	–	Mass Rapid Transit
NEMMP	–	National Electric Mobility Missions Plan
NMT	–	Non-Motorized Transport
NMV	–	Non-Motorized Vehicle
NUTP	–	National Urban Transport Policy
PM	–	Particular Matter
Pphpd	–	Passengers per hour per direction
ROW	–	Right of Way
UK	–	United Kingdom
USA	–	United States of America
VKT	–	Vehicle Kilometres Travelled

Chapter 1. Introduction

1.1. Background

As the cities sprawled outwards, the distance between the major economic centres and the other settlements increased. People depended on automobiles to cater to their needs, and over time, this became over dependency. Cities/towns and vehicular growth are considered positively correlated to economic growth. Therefore, as the cities expanded, the energy consumption, vehicle population, and greenhouse gas (GHG) emissions increased, whereas the quality of life in cities came down. If the earth's average surface temperature increases by 1.5 degrees Celsius from the pre-industrial levels, it will devastate humans and the natural environment[1]. This issue is addressed at important global conventions such as the Kyoto Protocol and the Paris Agreement. The countries have agreed to reduce their carbon emissions through various policy interventions.

1.2. Global Transportation

The transportation sector plays a critical role in global carbon emissions and warming due to its dependency on fossil fuels[2,3,4]. The increased vehicular growth led to various consequences such as congestion, longer travel times, accidents, and pollution[5]. Globally, 23% of the CO_2 emissions are from transportation (figure 1), out of which 74.5% come from the road transport sector[6] primarily due to increased usage of personal vehicles and vehicle kilometres (VKT).

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[1] NASA. (2022). World of Change: World Temperature. Retrieved from: https://tinyurl.com/ybohltz8

[2] Huang, F., Zhou, D., Wang, Q., & Hang, Y. (2019). Decomposition and attribution analysis of the transport sector's carbon dioxide intensity change in China. *Transportation Research Part A: Policy and Practice*, *119*, 343-358.

[3] Withey, P., Johnston, C., & Guo, J. (2019). Quantifying the global warming potential of carbon dioxide emissions from bioenergy with carbon capture and storage. *Renewable and Sustainable Energy Reviews*, *115*, 109408.

[4] Peters, G. P., Andrew, R. M., Canadell, J. G., Friedlingstein, P., Jackson, R. B., Korsbakken, J. I., ... & Peregon, A. (2020). Carbon dioxide emissions continue to grow amidst slowly emerging climate policies. *Nature Climate Change*, *10*(1), 3-6.

[5] Hensher, D, A. (2008). Climate change, enhanced greenhouse gas emissions and passenger transport – What can we do to make a difference? Transportation Research Part D. 13, 95-111.

[6] Ritchie.H. (2020). Cars, planes, trains: Where do CO_2 emissions come from?. Retrieved from: https://ourworldindata.org/co2-emissions-from-transport.

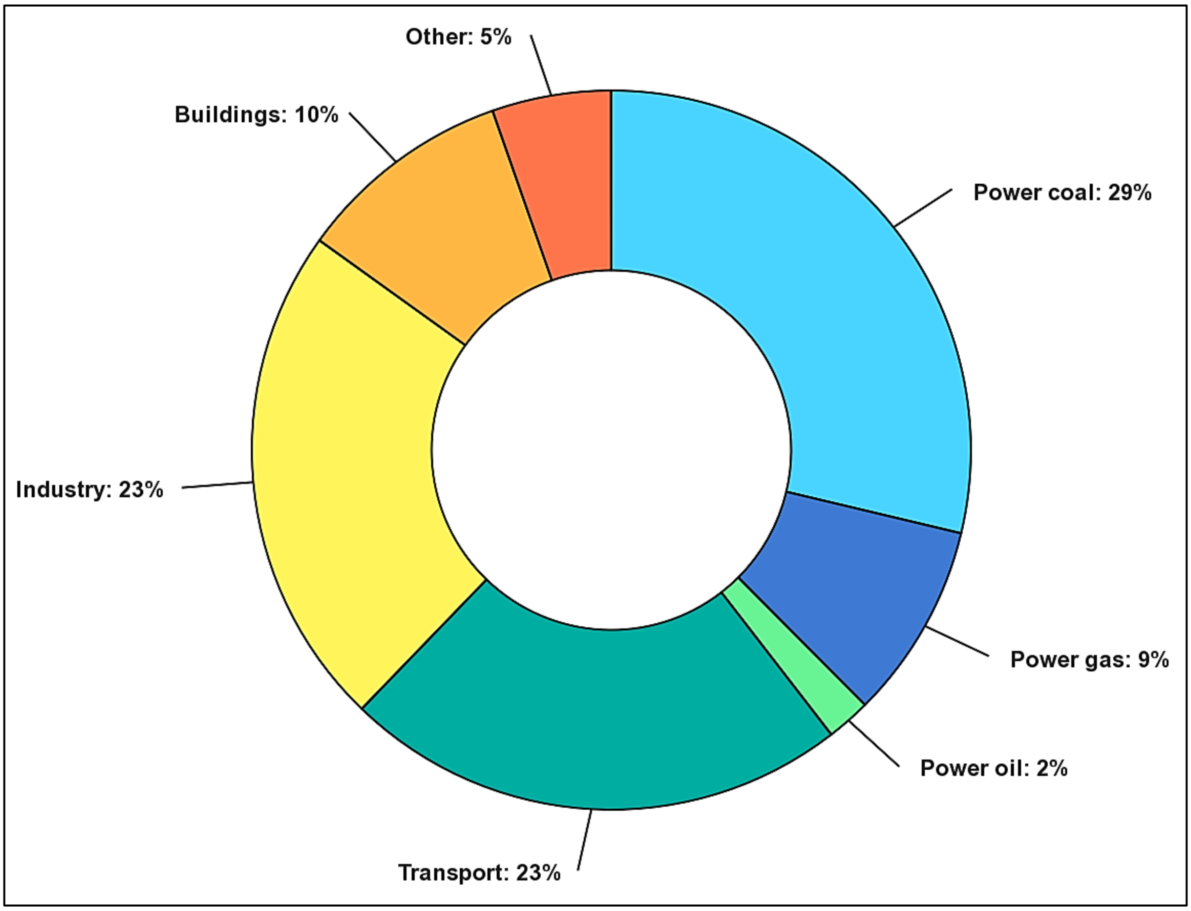

Fig. 1.1[7]: Global CO_2 emissions from transportation in 2018

Most developed economies are primarily car-dependent due to the affordability of owning a car. For instance, in the US, despite having a well-developed public transportation system and a substantial amount of funds being allocated to it, the public transport ridership is often low. This is primarily due to fewer service hours and long interchange times[8]. Similarly, other places such as Berlin, Madrid, Spain etc., face severe congestion problems. To solve these issues, globally, efforts are underway to shift from fossil fuel-based transportation systems to sustainable transportation systems such as public transportation and non-motorized transportation (NMT) systems.

1.3. Indian Transportation

India is one of the swiftly developing economies globally, and one-third of India's inhabitants

[7] IEA, Global energy-related CO2 emissions by sector, IEA, Paris. Available at: https://tinyurl.com/ya6njhmd

[8] Joseph Stromberg (2015), Vox - The real reason American Public Transportation is such a disaster. Retrieved from https://tinyurl.com/yctcps8p

reside in the urban region[9]. The total number of registered automobiles increased from 15.5 million to 26.2 million between 2011 and 2019 and reduced to 18.6 million due to the global chip shortage[10]. Amongst the registered automobiles, the share of two-wheelers and cars is 75% and 13% signifying high personal vehicle ownership, leading to congestion and pollution[11]. It is observed that about 99.9% of the Indian population resides in areas exceeding the air quality permissible limits set by the World Health Organization (WHO)[12 13]. The sector-wise CO_2 emissions for India from 1990 to 2018 are shown in figure 1.2[14].

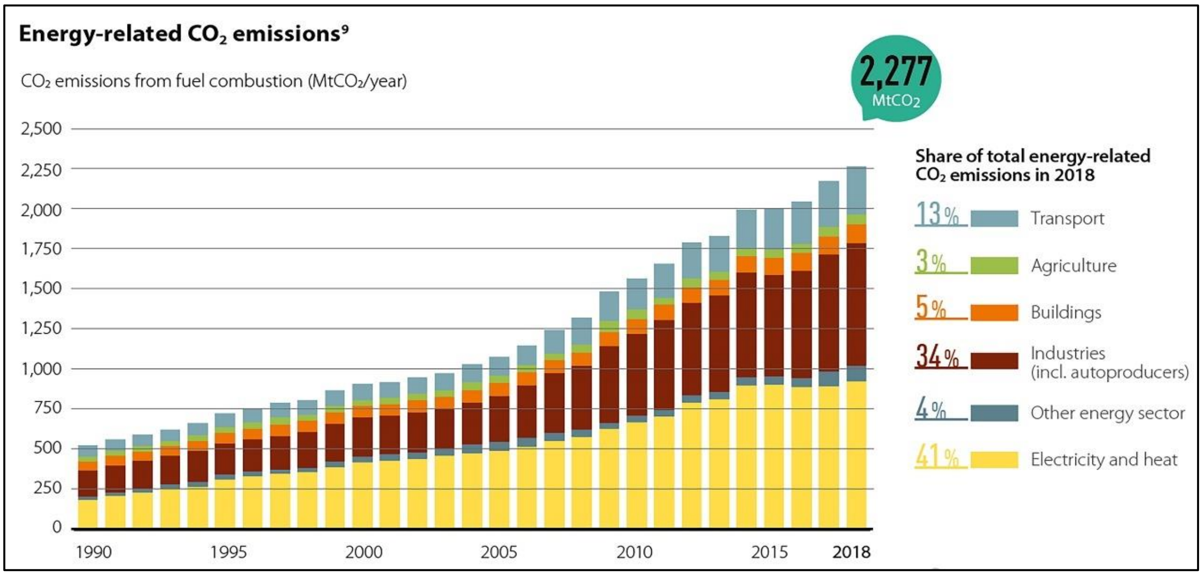

Fig. 1.2[14]: Annual CO_2 emissions in India for 1990 – 2018

Energy-related CO_2 emissions have increased almost four-fold since 1990. As of 2018, the transportation sector in India contributes to 13% of the country's CO_2 emissions, which has almost doubled since 2000. An increase in vehicle population contributed significantly to India's air pollution[15]. It is estimated that the passenger vehicles' yearly sales are likely to strike

[9] Singh N., Mishra T., Banerjee R. (2019). Greenhouse Gas Emissions in India's Road Transport Sector. In: Venkataraman C., Mishra T., Ghosh S., Karmakar S. (eds) Climate Change Signals and Response. Springer, Singapore.

[10] Sun. S. (2021). Sales of automobiles in India from financial year 2011-2019. (available at: https://www.statista.com/statistics/608392/automobile-industry-domestic-sales-trends-india).

[11] CEIC. (2021). India registered total motor vehicles. Retrieved from: https://www.ceicdata.com/en/india/number-of-registered-motor-vehicles/registered-motor-vehicles-total.

[12] GBD MAPS Working Group 2018 Burden of disease attributable to major air pollution sources in India (available at: www.healtheffects.org/publication/gbd-air-pollutionindia).

[13] Dimitrova, A., Marois, G., Kiesewetter, G., Samir, K. C., Rafaj, P., & Tonne, C. (2021). Health impacts of fine particles under climate change mitigation, air quality control, and demographic change in India. *Environmental Research Letters*, *16*(5), 054025.

[14] www.climate-transparency.org/wp-content/uploads/2019/11/B2G_2019_India.pdf

[15] Guttikunda, S. K., & Kopakka, R. V. (2014). Source emissions and health impacts of urban air pollution in Hyderabad, India. Air Quality, Atmosphere and Health. https://doi.org/10.1007/s11869-013-0221-z.

10 million by 2030[16]. Serious health issues are observed due to high exposure to air pollution (PM and NOx) in India[17]. Other issues include reduced travel speeds and increased travel times. In Delhi, the average travel speed during peak hours is almost 40% slower than the non-peak hours, and for every 5 kmph speed reduction, the NO_x levels have increased by 38%.

Due to its critical role in India's economy, it is challenging to decouple the economy from vehicular growth, and India needs to leapfrog to sustainable transportation. Similar to other countries, India has taken various steps to improve its public transportation system and NMT. As one of the main components of a comprehensive public transportation system that may include motorized and NMT elements, Bus Rapid Transit (BRT) delivers significant benefits to cities while requiring significantly less time and resources to build and begin operation than other comparable alternatives.

[16] Anyankar, N., Gopal, A., Sheppard, C., Park, W.Y., Phadke, A., (2017). Techno Economic Assessment of Deep Electrification of Passenger Vehicles in India. Lawrence Berkeley National Laboratory, Berkeley, CA, USA, pp. 1e30.

[17] Guttikunda, S. K., Goel, R., Mohan, D., Tiwari, G., & Gadepalli, R. (2015). Particulate and gaseous emissions in two coastal cities—Chennai and Vishakhapatnam, India. Air Quality, Atmosphere and Health. https://doi.org/10.1007/s11869-014-0303-6.

Chapter 2. Bus Rapid Transit

2.1. What is Bus Rapid Transit (BRT)

Multiple definitions for BRT convey one common thing: BRT is a high-quality bus-based transit system that delivers fast, comfortable, and cost-effective services at metro-level capabilities. It provides dedicated busways and iconic stations ideally aligned to the centre of the road, off-board fare collection, and fast and frequent operations[18]. It can be implemented relatively cheaply and is a critical technology in cities in developing countries. BRTs can support a shift towards more public transportation, thereby bringing about a range of benefits, including reduced congestion, air pollution and greenhouse gases and better service to people in developing countries. A typical high-end BRT station in the world-renowned Bogota city is shown in figure 2.1.

Fig. 2.1: BRT Station of Bogota City, Brazil

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[18] C40 Cities Climate Leadership Group. (2016). *Good Practice Guide: Bus Rapid Transit*. Available at: https://tinyurl.com/yd4j8ztj

BRT is becoming increasingly popular in many countries, and the number of cities adopting it is growing steadily because it is considered an upgrade of existing bus mass transit systems that emulate rail systems but with reduced costs and construction times. For example, the construction costs for a single kilometre of BRT are only 52% of the costs of a light rail system and 8% of those of massive rail system construction[19]. Some comparative data between BRT and more traditional transport systems are shown in Table 2.1.

Table 2.1: Comparison of the public transport systems parameters[20]

Type of Transit mode	Capital Costs (Million US$/km)	Capacity (passengers per hour per direction - pphpd)	Operating Speed (km/h)
Standard bus	-	3180–6373	10–30
BRT	Up to 15	Up to 55, 710	18–40+
LRT	13–40	Up to 30,760	18–40
Heavy Rail System	40–350	52,500–89,950	20–60

From table 2.1, it is evident that despite the low capital costs, the capacity levels of BRT are more than LRT and are comparable with the heavy rail system.

2.1.1. Vital elements for a successful BRT design

The success of BRT depends on sound corridor selection and a set of physical and operational elements that improve the speed of operations, increase capacity, and enhance safety. The Institute for Transportation & Development Policy (ITDP) has identified many crucial design elements associated with high-performing BRT systems. These elements include the following:

[19] Chatman, D.; Rayle, L.; Palacios, M.S.; Cervero, R. Sustainable and Equitable Transportation in Latin America, Asia and Africa: The Challenges of Integrating BRT and Private Transit Services; UC Berkeley Center for Future Urban Transport Institute of Transportation Studies Institute for Urban and Regional Development Department of City and Regional Planning University of California: Berkeley, CA, USA, 2019.
[20] Trubia, S., Severino, A., Curto, S., Arena, F., & Pau, G. (2020). On BRT spread around the world: Analysis of some particular cities. *Infrastructures*, *5*(10), 88.

- *Dedicated median bus lanes that are physically separated from mixed traffic lanes. Dedicated lanes are crucial for ensuring that buses can move quickly and avoid congestion*

- *A dedicated fleet of high-quality buses and high-quality stations with platforms that match the level of the bus so that passengers can enter and exit quickly and easily without climbing steps.*

- *Smart fare collection to enhance passenger convenience and improve efficiency.*

- *Level platforms to reduce boarding delays*

- *Well-designed intersections that restrict mixed traffic from taking turns across the bus way.*

A separate lane is essential for a BRT system to compete with a metro service. Besides, there are other factors based on which BRT can be classified into two categories, i.e., High-end BRT and BRT Lite, as shown in table 2.2.

Table 2.2: Comparison between High-end BRT and BRT lite

Function	High-End BRT	BRT Lite
Running ways	Exclusive lanes	Mixed traffic
Stations/Stops	High-end shelters which function as interchange hubs	Normal bus stops
Service Design	Frequent services; integrated local and express services; timed transfers	More traditional service designs
Fare Collection	Off-vehicle fare collection	More traditional fare media
Technology	Automated Vehicle Location (AVL); passenger information systems; traffic signal preferences; vehicle docking/guidance systems	More limited technological applications

Source: Cervero (2013)[21]

2.2. Benefits of BRT

An EMBARQ study by Carrigan et al. (2013)[22] tried to understand BRT's social, environmental, and economic impacts across four case study cities: Bogotá, Mexico City, Johannesburg, and Istanbul. The study finds four critical ways BRT improves the quality of life in cities. Another benefit of BRT is proposed by the C40 (2016)[18].

Travel time savings

The Indian traffic pattern is a mixed traffic condition where all vehicles share the same road space, and no lane discipline is followed. Therefore, providing separate lanes and prioritized traffic management allows the BRT buses to travel smoothly unhindered by other traffic. Additionally, the pre-paid fare management, High-frequency trips and level boarding services help reduce the time spent at the stops.

GHG and local air pollutant emissions reduction

The Vehicle Kilometres Travelled (VKT) of fossil-fuel-based vehicles is one of the critical factors for GHG emissions. BRT is a mass rapid transportation system with high occupancy levels compared to cars. This crucial factor leads to a significant reduction in VKT. Since buses

[21] Cervero, R. (2013). *Bus rapid transit (BRT): An efficient and competitive mode of public transport* (No. 2013-01). Working paper.
[22] Carrigan, A., King, R., Velásquez, J. M., Duduta, N., & Raifman, M. (2013). Social, Environmental and Economic Impacts of Bus Rapid Transit. *Washington, DC: EMBARQ*. Available at: https://tinyurl.com/y9xdonx9

are among the highest black carbon-emitting sources, equipping the BRT buses with clean vehicle and fuel efficiency technologies significantly reduces air pollution.

Traffic safety improvements

Since BRT has high occupancy, shifting to BRT leaves fewer vehicles utilizing the road space, creating a safer transport environment for all road users, particularly two-wheelers, pedestrians, and cyclists. The dedicated bus lanes reduce the interaction between buses and other vehicles, minimizing the accident risk.

Increased physical activity

The longer spacing distance between the BRT terminals allows people to walk to move between them. Additionally, the provision of BRT allows people to walk to the nearest stop by walking or by cycling. Although this increases the walking time of the commuters, the commute time is less than other modes due to the above-discussed reasons. Therefore, the overall travel times are still less than other vehicles that ply under mixed traffic conditions.

Meeting other social aims

BRT projects also have a social component that enables the city to deliver on its social justice and empowerment objective. For example, the city can identify and empower marginalized groups. The low-income groups primarily depend on public transportation for their commute. Therefore, providing BRT connectivity to the low-income neighbourhood will improve their accessibility and provide them with a pathway to new employment opportunities. By incorporating services such as taxis and auto-rickshaws into the BRT system as feeder services, their income can be sustained.

Its main drawback compared to other urban transport systems is its demand for urban space. BRT systems (like other transport initiatives) should be part of a comprehensive strategy of multiple measures to be most effective. These may include increasing vehicle and fuel taxes, strict land-use controls, limits, and higher fees on parking, and integrating transit systems into a broader package of mobility for all types of travellers. It should mainly be seen in competition with mass rapid transit (MRT) systems, primarily rail-based systems such as metro or light rail[23]. Because BRT contains similar features to a light rail or metro system, it is much more reliable, convenient, and faster than regular bus services. With the right design, BRT can avoid most of the causes of delay that typically slow down regular bus services, like being stuck in

[23] CTCN. (2022). Bus Rapid Transit. Retrieved from: https://tinyurl.com/y8owh8rq

traffic or queuing to pay on board[24]. BRT is an intelligent solution to cities' urban transport challenges as a safer, cleaner, and more efficient mode of transport that gives people more time for their personal lives.

2.3. Types of BRT

Based on travel patterns, expected demand, and available capital budget, the road-based public transportation system with priority can be categorized into four types. Within these categories, BRT can be further classified into two typologies: "closed" or "hybrid" systems. BRT systems, whether closed or hybrid, share vital features, such as dedicated median lanes, level boarding, and off-board ticketing. However, BRT systems differ in providing service beyond dedicated trunk corridors. While closed systems operate feeder services with separate vehicles, hybrid systems extend trunk services beyond dedicated corridors, providing direct service with the same vehicle[25]. The four types of road-based public transportation systems with priority are: Bus lanes, Busways, Closed BRT and Hybrid BRT.

2.3.1. Kerbside Bus lanes

Bus lanes typically consist of painted demarcations on the kerbside of a carriageway as seen in figure 2.2. Buses stop at standard bus shelters along the side of the road. Personal motor vehicles are generally restricted from using the bus lanes but may enter the lanes to access properties and make left turns. Well-enforced kerbside bus lanes may improve modest speed over mixed-traffic bus operations.

Fig. 2.2: An example of a Kerbside bus lane

Image source: Curbed

[24] Federal Transit Administration – FTA. (2015). Bus Rapid Transit. Retrieved from: https://tinyurl.com/y8t5mbq9

[25] Indian Roads Congress – IRC. (2017). Bus Rapid Transit (BRT) design guidelines for Indian cities: IRC 124-2017. Available at: https://tinyurl.com/yaxxu98l

2.3.2. Busways

Busways prioritize existing city buses with dedicated lanes, often in the median. The dedicated lanes may contribute to modest travel time savings, which is the prime difference between kerbside bus lanes and busways. However, busways miss many of the benefits of a mass rapid transit system as this system focuses little on high-end infrastructure development. A typical busway with a physical barrier is shown in figure 2.3.

Fig. 2.3: An example of bus way in Bengaluru, India

Image source: Deccan Herald

2.3.3. Closed BRT

Closed BRT systems tend to mimic rail-based mass rapid transit systems. The critical elements of a closed system are discussed in section 2.1. The high-class design features enable BRT systems to handle high passenger throughput—ranging from 12,000 pphpd with a single lane per direction to 45,000 pphpd with passing lanes—often with commercial speeds of 20 km/hr and above[25]. An example of such as system is Transmilenio in Bogota, Colombia.

Fig. 2.4: An example of a closed BRT system operated in Transmilenio, Bogota, Colombia

Image Source: Oscar Amaya

2.3.4. Hybrid BRT

Hybrid BRT systems combine the benefits of a closed BRT system with the flexibility of busways. The routes operated by the BRT fleet extend beyond the network of dedicated corridors, thereby providing passengers with direct connections and reducing the need for transfers. Otherwise known as "direct services," these extended routes are most effective if the extended portion of the route is relatively short and uncongested. Otherwise, delays in the service extensions can result in irregular bus arrivals once buses enter the BRT trunk corridor.

The key differences between the closed BRT and Hybrid BRT network operations are presented in figures 2.5 and 2.6[25].

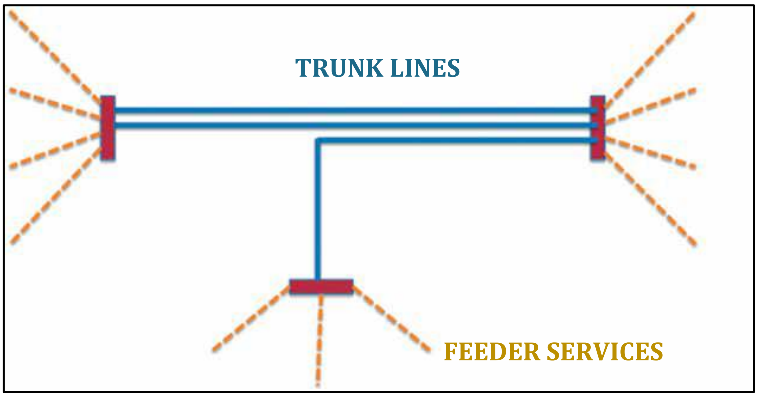


Fig. 2.5: Routes in a closed system are rationalized to operate as trunk and feeder services, where only BRT vehicles operate on the trunk corridor.

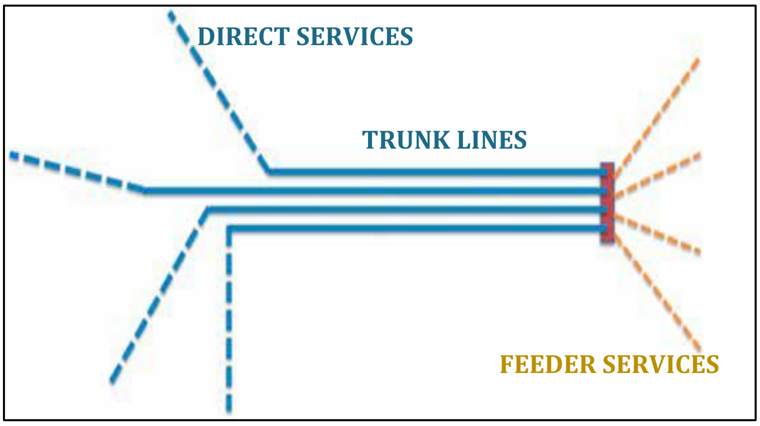


Fig. 2.6: In a hybrid BRT system, BRT buses operate in the trunk line corridor as well as the feeder area, thereby reducing the need for passenger transfers.

After recognizing the potential for improved customer service from hybrid configurations, many BRT systems, even those that began as closed trunk-and-feeder systems, have begun introducing direct services. BRT systems with hybrid services include the Guangzhou BRT (Guangzhou, China), Rainbow BRT (Pune-Pimpri Chinchwad, India), and Rea Vaya BRT (Johannesburg, South Africa). Hybrid systems can range from 2,000 pphpd to 30,000 pphpd at commercial speeds of around 20 km/hr[25].

Fig. 2.7: Guangzhou BRT in China

Image Source: gzbrt

Table 2.3 presents the typical features required for road-based public transport priority systems mentioned above.

Table 2.3: Typical Features of Road-Based Public Transport Priority Systems[25]

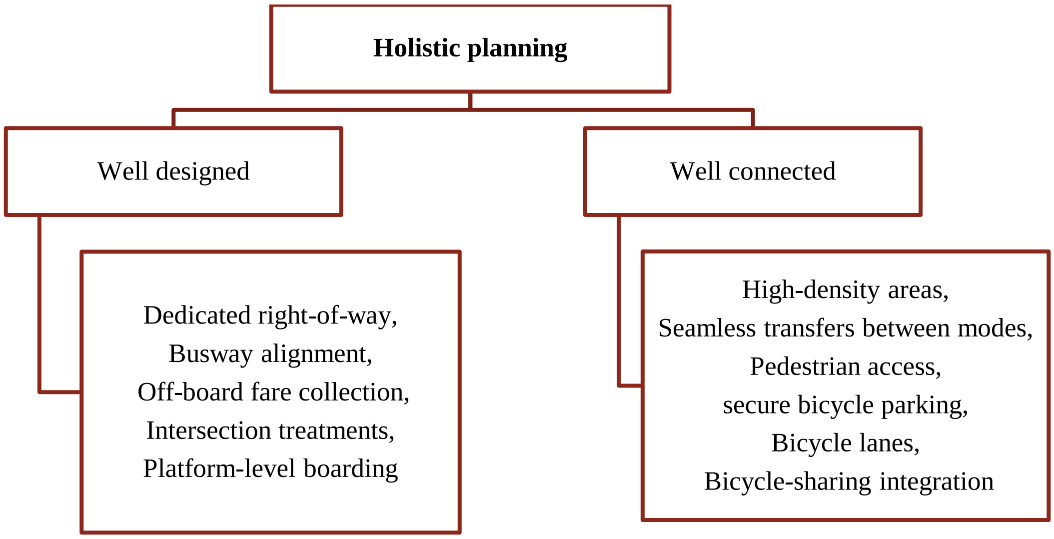
Features	Kerbside Bus lanes	Busways	Close BRT	Hybrid BRT
Physically separated corridor	-	Recommended	Recommended	Recommended
Dedicated fleet	-	-	Recommended	Recommended
Platform-level boarding for the entire fleet	-	-	Recommended	Recommended
Real-time passenger information	-	-	Recommended	Recommended
Off-board fare collection	-	-	Desirable	Desirable
Service extensions beyond trunk corridor	Recommended	Recommended	-	Recommended
Feeder services			Desirable	Desirable
Bus floor height	Multiple heights	Multiple heights	Low or high	Preferable low

2.4. Good practices for a successful BRT with Case Studies

In the BRT spectrum, various cities implemented multiple strategies to achieve desired outcomes. These strategies depend on various factors such as the national and state-level policies, project financing, engagement of the public, institutional framework etc. The BRT strategies should be mechanised appropriately based on the factors influencing a locality. Some of the best practices adopted by many cities are discussed in the following sections.

2.4.1. Adopt holistic planning for a high-capacity BRT corridor

Holistic planning ensures that a BRT system is both well designed and well connected and is able to function as the centrepiece of a multi-modal transport network.



This is crucial to delivering a high capacity and convenient system for people, enabling the maximum shift out of private vehicles, thus reducing carbon emissions and ultimately benefiting the highest number of people in the city.

The TransOeste BRT in Rio de Janeiro, Brazil and the Guangzhou BRT in China are classic examples of holistic planning. The TransOste BRT began with 40 km in 2012, transporting 1.2 million passengers daily. It operates over a 168 km network carrying 3.5 million passengers per day. Due to its extensive network coverage and connectivity to other modes such as the subway, the public transportation mode share increased from 18% in 2012 to 47.3% in 2015. This reduced the inner-city trip travel from 1 hr 40 min to 45 min and air pollution. The value of time (VoT) saved on the trips amounts to $23 million a year. TransOeste has proved to be because of the city's holistic planning approach and overarching transport improvement plan. The feeder bus routes were also identified and optimized/rationalized as needed. The overall system has constantly been upgraded based on the regular feedback from the commuters.

Case Study

Guangzhou's BRT received the Institute for Transportation and Development Policy's Sustainable Transport Award in 2011. High-density area, flat-rate subsidized bus fares, discounted smart cards, direct access to metro or rail stations, bridges from bus stations to adjacent buildings, bike lanes, and walkways make this BRT one of the best in the world. Guangzhou BRT reduced traffic congestion and increased the speed of buses and mixed traffic by 29% and 20%, respectively, saving 52 million commute hours, worth US$ 24 million, in 2010. The city considered very carefully how the new BRT corridor would fit in with people's expectations and needs, as well as with existing modes of transit, e.g., current bus routes, walking and cycling options in the city, etc.

The success of these BRTs is because of the holistic approach where the economic and social factors (demand, population, fare, accessibility, landmarks, and community sites) and geographic factors (road width, elevation, and expansion), and technological factors (vehicles, real-time monitoring, signals, fare integration) are all integrated into the planning and implementation phases of BRT[18].

In India, Janmarg BRT of Ahmedabad and Surat BRT have an extensive network connecting central locations and socio-economic communities. These two BRT systems also have a closed BRT type system, which provides them with exclusive right of way and higher levels of service. Although the Indian BRT's have emphasized providing cycle ways and footpaths, it requires a significant improvement and continuous maintenance to be much more successful.

2.4.2. Develop benchmarking and measure the impacts of BRT

Benchmarking and measuring the impacts of BRT is a crucial area of best practice, as it enables cities to assess and then demonstrate the value of their BRT system to other stakeholders. These assessments vary depending on the local conditions and objectives of the city government but should include elements like time-saving, emissions reduction, air pollution improvements and subsequent health impacts. Other factors like retail and economic impacts and other aspects of social evaluation can also be considered by cities.

This measurement can enable a city to use the data in various ways – to demonstrate the success of a corridor, the sustainability of the system, or show how social aims, e.g., reducing inequality, have been met. This benchmarking can form the basis of communicating to stakeholders and/or politicians to meet the city's broader transport and social objectives. If data are available from other cities, comparing delivery across two or more cities is another effective way to identify future improvements required in the system.

Case Study

Istanbul's Metrobüs system was designed to provide low cost, rapid service to the city's inhabitants travelling east to west and vice versa. It is the first bus rapid transit system in Turkey and is the first transcontinental BRT in the world. With low costs, Istanbul's BRT was one of the best performing BRTs worldwide. There is a reduction in travel time, GHG emissions and local air pollutants, as well as improved road safety and physical activity. Istanbul's Metrobüs BRT system is estimated to reduce CO_2 emissions by 167 tons/day and cut daily fuel consumption by more than 240 ton-litres – this equates to 60,955 tonnes per year. It also identifies the socio-economic groups benefiting the most from the Metrobüs system. This analysis forms a good model for other cities to benchmark their systems. It assesses which groups are helping the most and why, as well as undertaking a comprehensive cost-benefit analysis to guide future improvements or expansions of their BRT systems.

The primary reason for this success is that the city undertakes comprehensive surveys through the IETT (the Istanbul Electricity, Tramway and Tunnel Survey) annual rider assessments. This enables the city to continuously assess the service quality and improve it, ensuring the BRT remains an attractive mode of transport for people to use. A high-quality bus rapid transit system can impact the quality of life, productivity, health, and safety of people living in cities. Therefore, examining these impacts in depth can help a city assess the net benefits to society of a BRT project, an important criterion when deciding to build or expand a BRT system.

2.4.3. Focus on strong stakeholder engagement and communications

Stakeholder engagement is crucial to getting a BRT project off the ground, as projects often face several preconceptions from decision-makers, stakeholders, press and citizens. These can include concerns about taking already congested road space away from other users and problems about the performance of BRT systems versus rail. Until a system is in place and delivering benefits for them, people can be opposed to the idea of a BRT system due to fear of the unknown. A strong and well thought out stakeholder engagement campaign is crucial to ensure buy-in and commitment to the project and encourage ridership for the system. Elements of a good campaign will include identifying all groups likely to be affected by the project and tailoring appropriate communications to them through advertising, community meetings, leaflet drops, surveys, regular consultations on plans, etc.

Case Study - 1

Like other growing cities, Buenos Aires faced significant traffic congestion and transport-related air pollution problems. As a result, the city developed a Plan for Sustainable Mobility to tackle these problems, with the BRT system forming a key element of this Plan. Stakeholder engagement has been crucial for the city's successful BRT delivery, enabling it to overcome initial negative publicity to eventually deliver a BRT system with a highly positive reaction from the media and citizens alike. This is partly due to the strong stakeholder management and time spent working with affected groups to overcome initial concerns. The BRT system now consistently rates among the best initiatives launched by the city administration, with positive impacts on everyday life.

By 2015, the BRT corridors in Buenos Aires carried 1.2m people across the city and resulted in 49,000 tonnes of CO_2 emissions reduction per year. So far, the introduction of BRT lines on key routes has cut travel times by 20 - 40% on average, although in some cases, it has been by 50% or more. By the end of 2015, there will be 56 km of Metrobus corridors connecting the main transport hubs in the city, and 1.2m people will benefit every day. Adopting articulated buses on some routes has also led to a further reduction in carbon emissions. All of these benefits have been made possible by the city's substantial work on engagement and the support generated across the full range of stakeholders.

The city's strategy was to phase in the implementation of the BRT. The experience and positive results from the first route encouraged the city to proceed with the delivery of more corridors, accompanied by active opinion polling, awareness campaigns and the launch of a dedicated educational website. In subsequent stakeholder surveys, over 90% of commuters gave positive feedback for Metrobus.

Case Study - 2

Tshwane's BRT system (A Re Yeng or "Let's Go"), approved in 2011, forms part of the City of Tshwane's 2055 Growth and Development Strategy. It aims to provide an alternative to private cars and minibuses in the city, offering a faster, regular, more equitable and reliable transport option for getting into the city centre. Aware of the economic losses this may cause for minibus and taxi operators along the corridor, Tshwane involved the affected stakeholders in the negotiations from the beginning of the project and provided for their integration into the BRT system, thus building a unique relationship between the city and the transport industry. Those affected by the transport system change received financial compensation were offered shareholder position in the new Bus Operating Company (BOC), or were directly incorporated in the BRT system operation (as bus drivers or other employees). The pilot corridor for Tshwane's BRT is now in place, and expansion of the system is continuing.

The project hopes to carry 100,000 passengers daily when the almost 70 km BRT corridor was fully operational in 2020. Around 209,000 tons of CO2 will be reduced annually if Tshwane achieves its goal of shifting 10% of journeys to BRT. With more commuters shifting from private to public transport, the city also expects fewer traffic accidents. The Tshwane BRT bus fleet will also run on low-emission diesel engines and compressed natural gas and emit 34% less CO2 and 24% less NOx than a standard diesel counterpart.

Early, robust and continuous engagement with stakeholders to ensure they are on board with the plans as much as possible and are not fearful of/ in opposition to the new system being introduced were key to successfully implementing the BRT system.

Many cities worldwide have existing minibus or taxi industries in place, whose livelihoods may be perceived to be at risk from the introduction of a new BRT system. Tshwane's approach is an excellent example of including the industry and other stakeholders early in the planning phase and finding their roles in the developed BRT system.

The BRT system in India cannot be termed as successful because not a single BRT in India achieved their projected ridership. The primary reason for less ridership is strong opposition from the public. Even the Ahmedabad BRT faced public opposition, and the Delhi BRT was discontinued for the same reason. In contrast, despite public opposition, Indore BRT conducted a citizen sensitization campaign, free trial runs, passenger feedback based on continuous improvement, etc. Currently, Indore BRT is the only BRT running in profits in India.

2.4.4. Integrate BRT with other means of public transport and urban planning

As cities contend with resource constraints and environmental pressures, increasing public transport availability through introducing a BRT system is a very effective way of meeting transit demand. But introducing a BRT in isolation is not enough, and more connected transit-oriented urban policies are crucial to improving the long-term sustainability of cities. More holistic, transit-oriented urban policies would reduce CO_2 emission growth by 30% in Chinese and Latin American cities and 40% in Indian cities compared to their baseline scenarios. This is also better and more efficient for cities where compact, transit-oriented development can have a massive economic benefit. For example, Copenhagen only spends 4% of GDP on transport while sprawling, car-focused Houston spends 14%.

Case Study

Curitiba was the first city to develop Bus Rapid Transit in 1974. The city continues to be a transit innovator, recently launching a program to implement hybrid and electric buses. Curitiba's BRT system was developed as an integral part of an overall Masterplan (1966). Its main objectives included radial city expansion along five corridors, integrating land use and transport, and creating a dedicated planning institute IPPUC. The Masterplan is revised every 10 years, and the latest revision includes a comprehensive urban sustainable development plan for the next 50 years. In the 1990s, after creating the BRT system, Curitiba tackled integrating all bus lines into the Rede Integrada de Transporte, with a hierarchy of bus service types and standard terminals, allowing passengers to use one ticket for as many bus lines as necessary. In 2011, BRT expanded its carrying capacity with the implementation of the Direct Line – a bus stopping at fewer stops, reducing substantially longer-distance travel time. In 2012, the city also initiated the integration with a bicycle network, expanded through the 2012 Bicycle Masterplan. Curitiba also continues innovation in other parts of its transport sector: since 2014, they have promoted 100% electric buses.

Today, 80% of travellers use the BRT system, which carries around 2 million passengers daily. The BRT has 30 hybrid buses, reducing overall fuel needs by 35% and limiting pollutant emissions (NOx, particles). Curitiba's BRT system model has already been replicated in more than 150 cities worldwide.

The success of the BRT system is related to its integration into Curitiba's master planning and support from different stakeholders. On the micro-level, some employers subsidize their employees who use the BRT system. On the macro level, urban planning is integrated with the BRT system, with urban growth being restricted to corridors of growth – along key transport routes – using a combination of control and incentives, such as extended permitting for developers that wish to construct taller buildings close to the transit corridors.

Cities developing or updating urban development plans, planning to upgrade their transport system, or looking into implementing a BRT system, can all use this approach to ensure that different transport modes are well integrated and constitute the most efficient system possible.

When it comes to India, while all the BRT systems have a multimodal transportation hub as one of their visions, there is still scope for significant improvement. Currently, most BRTs have the bus as their primary feeder service but are inadequate, forcing people to use autorickshaws[26].

2.4.5. Utilize innovative financing mechanisms.

BRT projects have typically been financed in a range of ways. This has included: government grants (national or municipal); loans; revenues from fuel tariffs, fares, advertising; local commercial bank financing to operators, etc. In addition, cities are starting to explore more innovative means of financing new BRT systems or expanding existing ones, such as through Green Bonds, as discussed in the Johannesburg example below. Carbon credits are also an emerging area of interest for C40 BRT Network member cities and are currently being explored in more detail.

Case Study

The city of Johannesburg has pioneered a municipal "Green Bond" in South Africa to raise funds to help respond comprehensively to climate change and ensure sustainable management of resources. The Green Bond issued by the city in June 2014 is worth ZAR1.5bn (approx. US$143m) and is funding projects across a range of sectors, including 150 new dual-fuel buses and converting 30 buses to biogas. The Green Bond shows the city its commitment to environmental stewardship while receiving a market-related financial return. The Green Bond has provided the city with a new funding source to improve and expedite the implementation of its climate change mitigation strategy and move Johannesburg towards a low carbon infrastructure.

Johannesburg had political leadership supportive of exploring innovative mechanisms to finance upcoming "green" projects. In addition, the city's investment-grade credit rating helped them take the bond to market and for it to receive a very positive response. In addition,

[26] Trivedi, P., Raol, J. D., & Shah, J. Evaluation of Feeder System between BRTS and Proposed Metro Station of Ahmedabad.

the city also benefited from international guidance, such as the Green City Bonds Coalition, which – in cooperation with C40 - recently released the specialist Green Muni Bonds Playbook. The use of Green Bonds to finance low carbon buses (and green projects more broadly) offers the opportunity for creditworthy cities to access large-scale debt finance to introduce clean buses into their BRT (and other cities) fleets. The cost of finance will depend on the structure of the bond and the creditworthiness of the project or the issuer, but it is generally a competitively priced source of long-term finance. It also allows cities to grow and diversify their investor base, increase collaboration between city environment and finance departments, and publicly highlight a city's long-term commitment to sustainable development.

Like Johannesburg's green bond initiative, India issued green bonds in 2021. The green bond issuance in India in 2021 was exceptional and will set a new record in 2022. India issued $6.11 billion of green bonds in 11 months of 2021[27]. Since the LUB's in India depend on the Central and State governments for funding, they can raise funds through green bonds. Sustainable public transport in India's cities is crucial for citizens' essential quality of life and a clean environment. Through green bonds, the LUBs can raise funds and utilize them for sustainable transportation infrastructures such as bus transportation and other mass transportation systems like BRT and MRT. According to the McKinsey Global Institute report on India's urban awakening, India has the potential to reduce GHG emissions from vehicles by nearly 100 million tons of CO_2 equivalent (CO_2e) by 2030 by shifting toward public transport. Therefore, it is crucial to utilize the green bonds effectively.

[27] https://economictimes.indiatimes.com/markets/bonds/decoding-green-bonds-india-market-and-how-to-invest-in-it/articleshow/90230488.cms?from=mdr.

Chapter 3. Global Trends in BRT

3.1. Global overview of BRT

The BRT system is a form of public transportation developed in 1976 in Curitiba, Brazil and is considered to be the pioneer of BRT[21]. It was introduced to enhance the customer experience and provide them with improved transit services. Since BRTs inception, many other Latin American countries, including Ecuador, Colombia, Mexico, Peru, and Chile, adopted Brazil's BRT model[21]. The success of BRT in these countries resonated in Europe, where cities in the UK, including Leeds, London, Ipswich, and Reading, implemented this system. Similarly, many Asian countries, such as India and China, also implemented the BRT system.

3.1.1. BRT by Region

Currently, the BRT system is implemented across 181 cities worldwide, covering a network length of 5450 km and carrying an estimated 34 million passengers every day[28]. A global overview of the BRT system is presented in table 3.1. The data presented in the subsequent sections are for the period between 2013 and 2015.

Table 3.1. Global overview of the BRT[28]

Region	Passengers per day	Number of cities	Length (Km)
Latin America	20,829,474 (61.99%)	61 (33.7%)	1,960 (35.96%)
Asia	9,238,060 (27.49%)	45 (24.86%)	1,691 (31.03%)
Europe	1,613,580 (4.8%)	44 (24.3%)	875 (16.05%)
Northern America	988,683 (2.94%)	21 (11.6%)	683 (12.53%)
Africa	491,578 (1.46%)	5 (2.76%)	131 (2.41%)
Oceania	436,200 (1.29%)	5 (2.76%)	109 (1.99%)

Among various countries that adopted BRT, the Latin American region has the largest BRT network of 1960 km across 61 cities. It carries approximately 21 million passengers daily, accounting for 62% of the global BRT passengers.

[28] Global BRT Data. (2021). Evolution of a number of cities per year. Retrieved from: https://brtdata.org/panorama/year

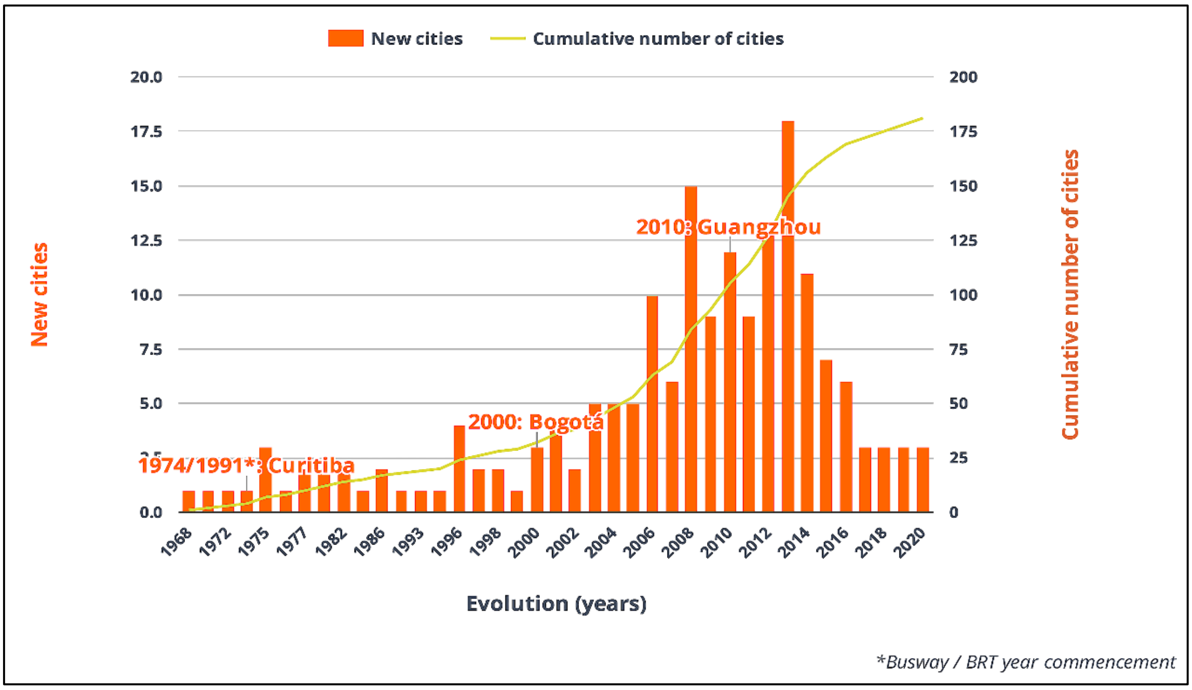


Fig. 3.1 : Evolution of number of BRT cities per year[28]

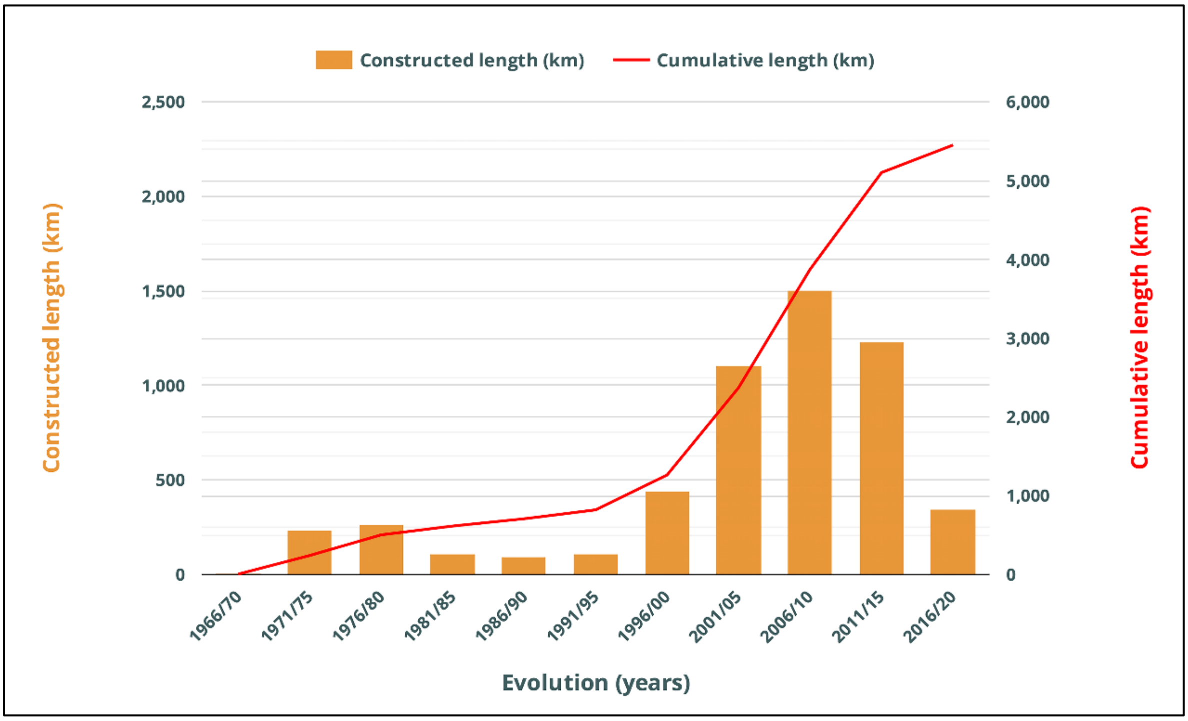


Fig. 3.2: Evolution of BRT network[28]

Initially, the number of cities that adopted BRT grew steadily till early 2000, as shown in figure 3.1. Since 2004, the number of cities that adopted the BRT system has increased. Consequentially, the BRT network has multiplied, as evident from figure 3.2.

3.1.2. BRT by Country

Since its first BRT in Curitiba, Brazil has become a global leader in building the BRT system. Figure 3.2 compares select countries with the number of cities that adopted BRT. With the success of Curitiba's BRT, Brazil has many of its features to 23 other cities making it the country with the highest number of cities having BRT. Curitiba is today best knowns for using BRT to channel urban growth along compact, mixed-use corridors that attract transit riders.

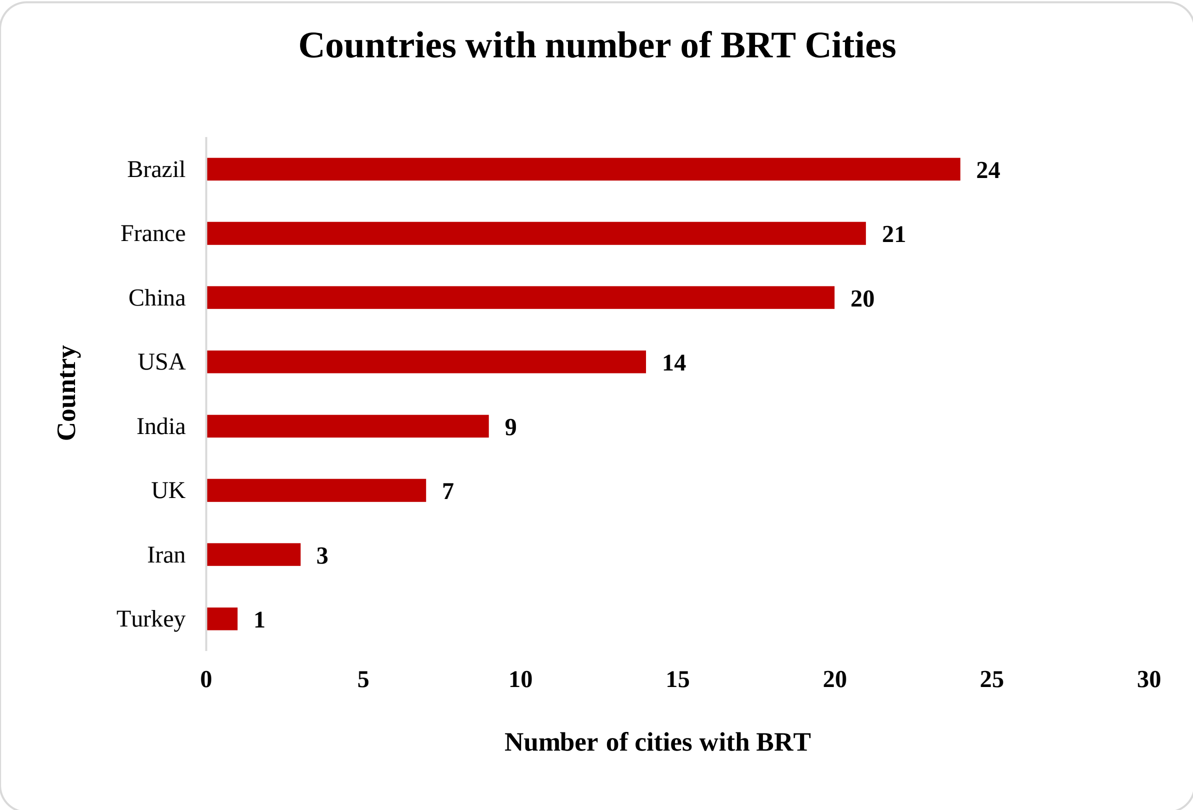


Fig. 3.3: Countries with a number of cities having BRT

In the footsteps of Brazil, France and China had aggressively built BRT systems across 21 and 20 cities, respectively. India, with 9 cities having BRT systems, globally ranks 5th for the country with many cities having BRT. Besides cities adopting BRT, the system is beneficial if it can attract more passengers. Attracting more passengers to BRT reduces the VKT, reducing congestion and pollution and improving road safety. Figure 3.3 shows the top 15 countries' passenger demand per day.

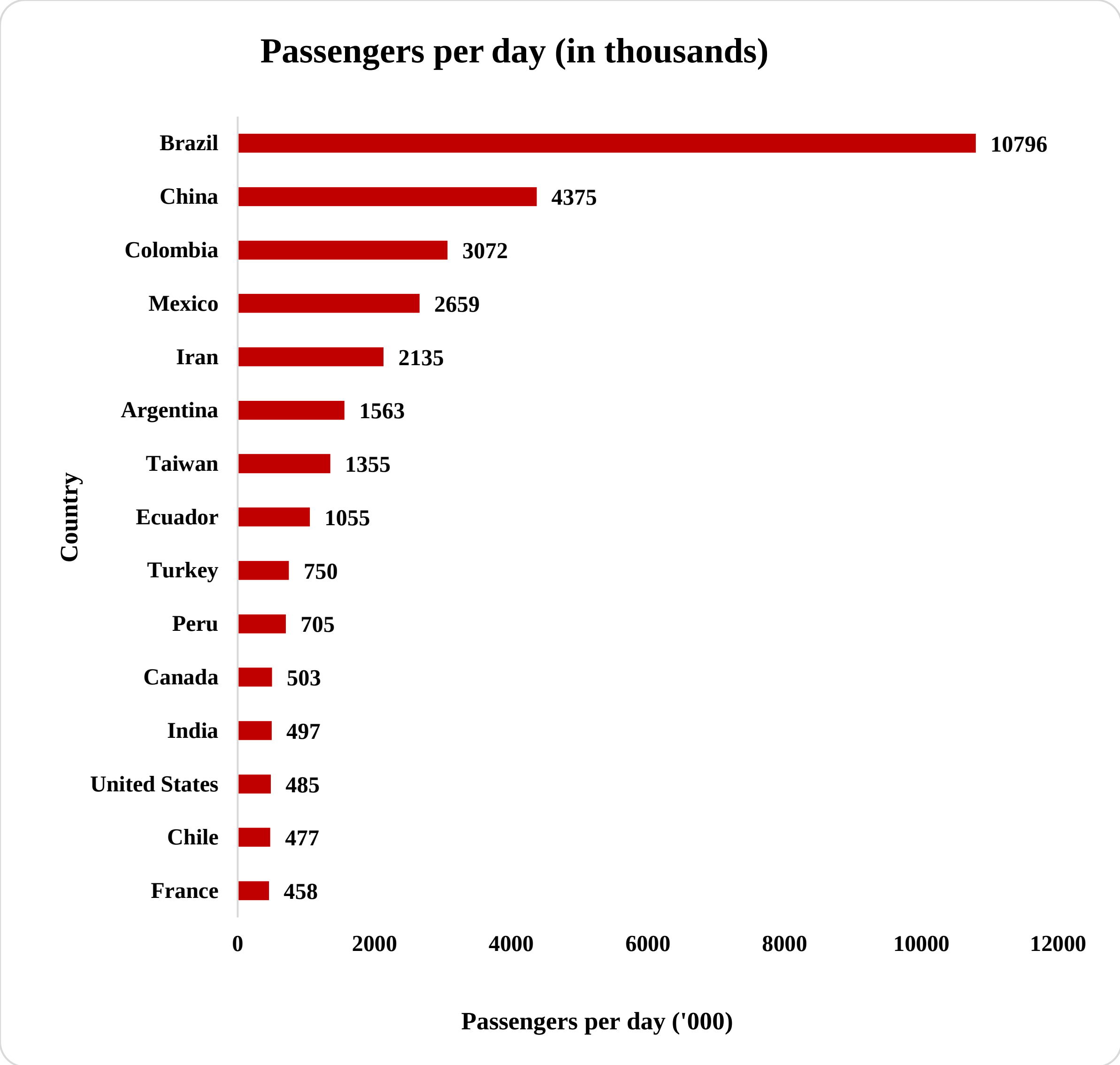


Fig. 3.4: Top 15 countries' BRT passengers demand per day

Brazil, with the highest number of BRT cities, carries more passengers per day on BRT, followed by China in second place. India, with a passenger demand per day of approximately 497,000, ranks 12th. Among the top 10 countries, six are from Latin America, and three are from Asian regions. This implies that these two regions are at the forefront of BRT systems worldwide. Consequently, the BRT network's length has also increased in these countries. However, in some countries, despite having more cities with BRT, the number of operating corridors is less than the length of BRT. Figure 3.5 shows the length of the BRT network of the same cities presented in figure 3.4.

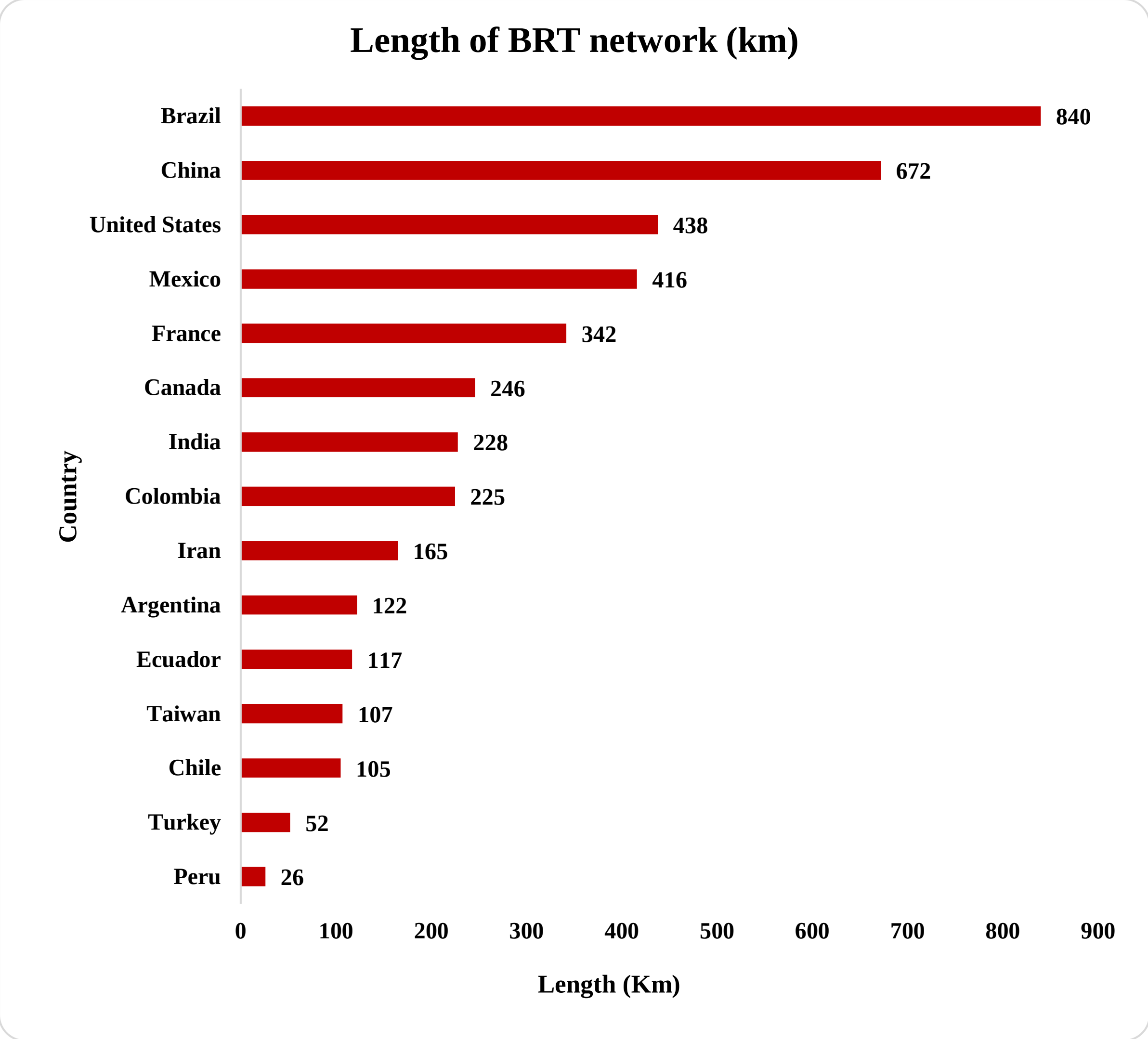


Fig. 3.5: Length of BRT of top 15 cities (based on passenger demand)

Similar to earlier observations, Brazil has the longest BRT network, followed by China in 2nd place. India, with 228 km, has the 7th largest BRT network. The point of interest here is that countries such as France and the United States of America (USA) built extensive BRT systems across many cities and have large networks compared to India. However, figure 3.4 indicates that despite the USA and France having well-developed public transportation systems with substantial funding, the ridership is often low. This primary reason the US has low ridership is due to fewer service hours and long interchange times[29].

3.1.3. BRT Performance

The BRT length is a supply indicator, and BRT passenger demand per day is the demand

[29] Joseph Stromberg (2015), Vox - The real reason American Public Transportation is such a disaster. Retrieved from https://www.vox.com/2015/8/10/9118199/public-transportation-subway-buses.

indicator. Combining these two indicators will give BRT performance: Number of passengers per day per kilometre of BRT busway. Figure 3.6 shows the BRT performance of the top 15 countries.

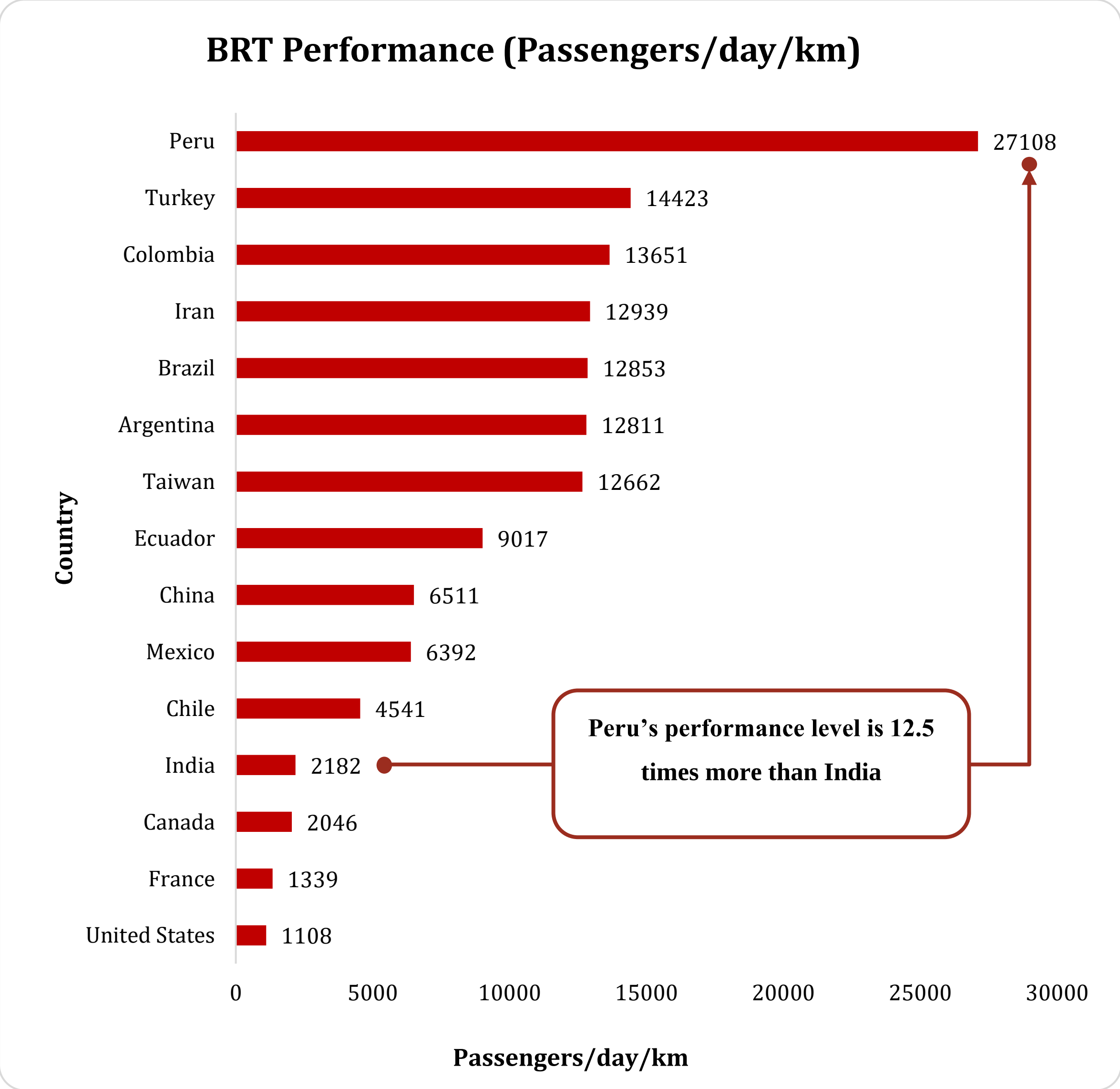


Fig. 3.6: BRT Performance of top 15 countries (based on passenger demand/day)

Surprisingly, Peru and Turkey are the last two countries with BRT networks among the top 15 countries. However, in performance, Peru ranks 1st, followed by Turkey, as seen from figure 3.6. The BRT network of Peru is approximately 32 times less than Brazil's, yet it carries almost twice the passengers per day per kilometre as Brazil. This could be primarily because the BRT network of Peru (Lima BRT) is significantly small and has a higher public transport mode share and operating speeds than Brazil's Rio de Janeiro. This allows it to carry more passengers within a one-hour time frame. However, things are contrary at the macro scale.

Despite Brazil having the largest BRT network and carrying more passengers daily, the performance levels of Brazil's BRT still have a scope to improve. The BRT performance in India is relatively poor and stands 12th among the top 15 countries. As compared to Peru, India's BRT performance is 12.5 less. This implies that for India to have a smooth, high capacity and fast BRT system, India has to put substantial effort.

BRT system performance can vary significantly depending on design characteristics and level of integration with other transport modes. For instance, a BRT corridor with exclusive, segregated bus lanes will be able to move more passengers in an hour than a corridor where buses operate in bus-priority lanes, which also permit access to mixed traffic. Bypassing lanes at stations (which allows an arriving bus to pass buses while boarding passengers at the station) enable express routes to skip certain stations and reduce travel times for some passengers. Bus speeds will also be higher on corridors with fewer intersections. Not all corridors have the same travel demand, so there is no one-size-fits-all BRT. A city should aim to implement the highest quality BRT that meets the travel demand and mobility needs on a particular corridor. Understanding the range of BRT's performance may help decision-makers identify the right fit for their specific urban context[22].

Disaggregating data to the city level provides a better understanding of the BRT performance. Based on the available data, the performance of a few Indian cities is compared with other cities worldwide. The country with high passenger demand with a region is selected for the city selection. Further, the top two highest passenger demand cities are chosen in each country. This process is repeated for all the regions on the https://brtdata.org/ website. The performance of these cities is compared based on the daily passenger demand, peak load, and BRT frequency.

Daily Passenger Demand is the number of daily passenger trips carried on the system. Linked passenger trips are used rather than boarding, so a transfer between a feeder route and trunk corridor is counted once. Figure 3.7 shows the daily passenger demand across the selected cities.

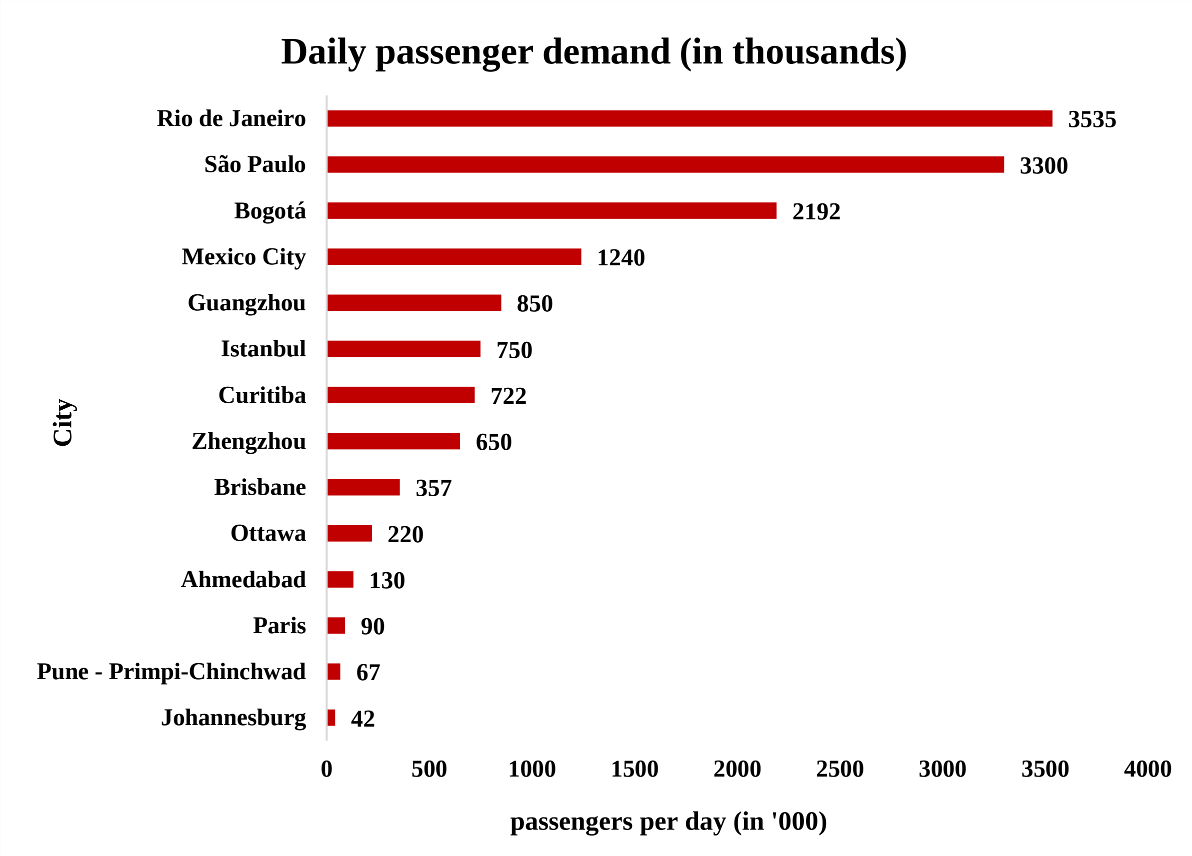


Fig. 3.7: Daily passenger demand (in thousands) across selected cities

Rio de Janeiro, with 35,35,000 daily passenger demand, stands first among the cities and is one of the high-capacity BRT systems. The highest-volume systems are designed to maximize capacity. The lower-capacity systems have been tailored for the needs of a lower-demand corridor or may not yet have reached their carrying capacity. In India, Ahmedabad city has the highest daily passenger demand of 130000 persons/day. However, the demand is significantly lower than Latin American or China's BRTs, despite Ahmedabad's population density (9900 persons/km^2)[30] being almost twice that of Rio de Janeiro (5377 persons/km^2)[31].

Peak load is the number of passengers carried in one direction between two stations in an hour. For planning purposes, it is critical to know the peak load demand on a typical day throughout a single cycle (also during the peak period). Peak load is the "maximum hourly load on the critical link" (MaxLoad). Identifying this location and this load is paramount in any service planning exercise as it is the load at this point that will determine the fleet needed and the appropriate vehicle size.

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[30] World Population Review. (2022). Ahmedabad City Population Density. Retrieved from: https://worldpopulationreview.com/world-cities/ahmedabad-population.

[31] World Population Review. (2022). Rio de Janeiro Population Density. Retrieved from: https://worldpopulationreview.com/world-cities/rio-de-janeiro-population.

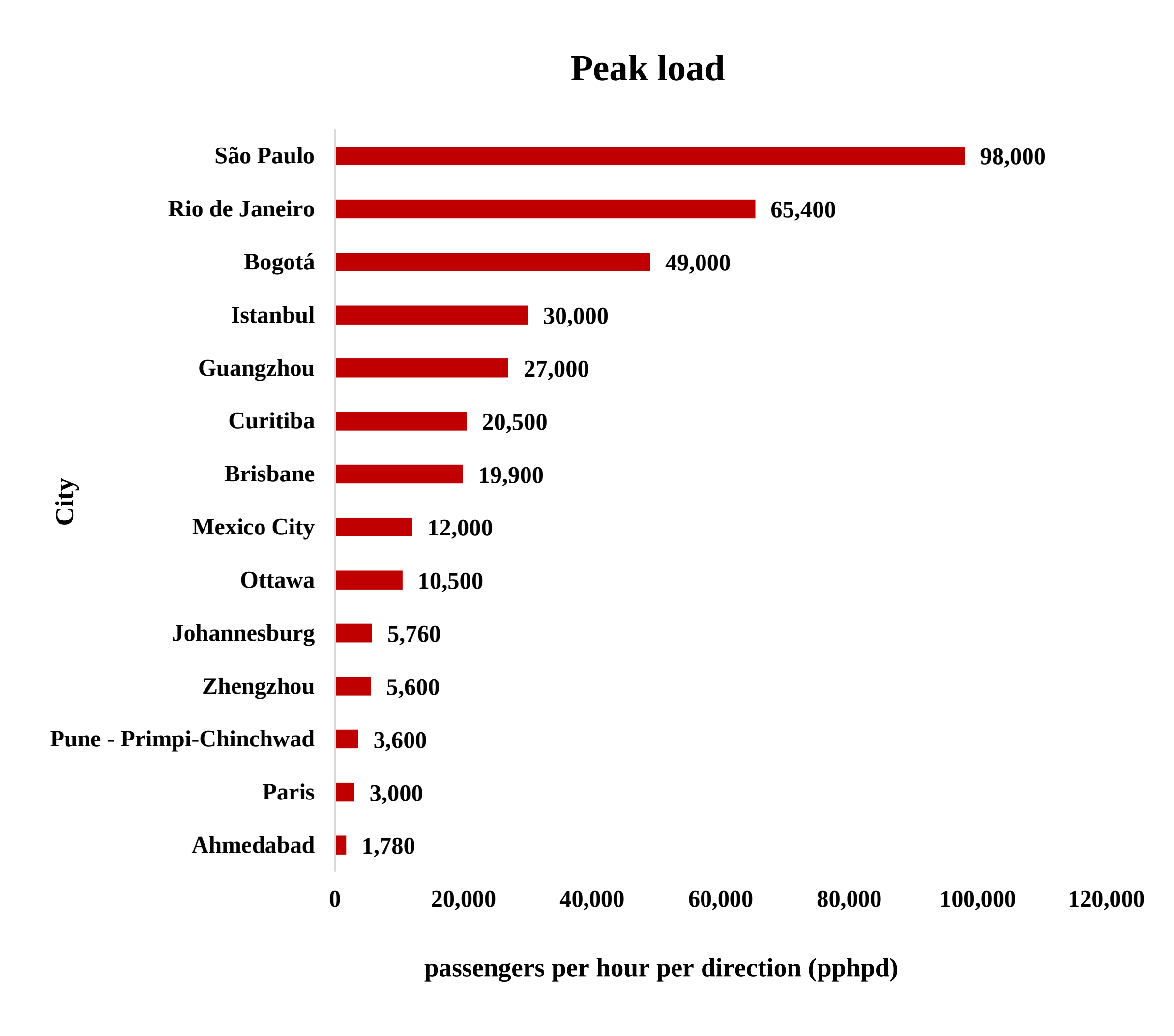

Fig. 3.8: Peak load (passengers per hour per direction) - Comparing Indian cities with others

The peak load of selected cities is shown in Figure 3.8. Similar to the previous observation, the high-capacity BRT systems, Sao Paulo and Rio de Janeiro, showed the highest peak loads. Although Ahmedabad showed the highest daily passenger demand in India, the peak loads are high for the Pune-Pimpri-Chinchwad BRT. Because of Pune's high-frequency BRT system and shorter network, the number of passengers transported between the destinations is higher than in Ahmedabad.

BRT bus frequency is the number of buses per hour and is an operational efficiency indicator. High-frequency BRT systems reduce the waiting time of the passengers, thereby reducing the overall travel time. Since time is a critical component in choosing a particular mode of transport, BRTs with shorter travel times will attract more people towards it. Figure 3.9 presents the bus frequency across select cities.

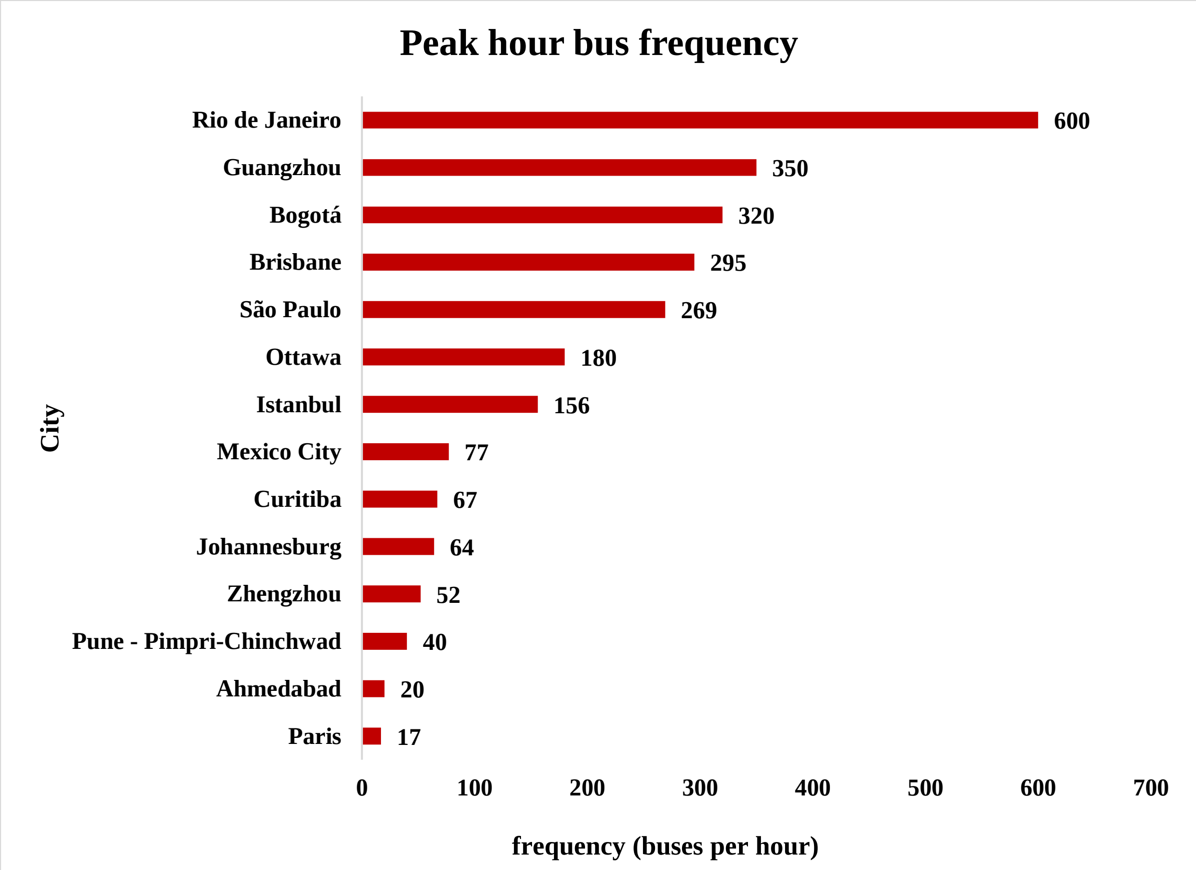

Fig. 3.9: BRT bus frequency (buses per hour)

Rio de Janeiro has 600 buses per hour, far ahead of any BRT regarding frequency. Previous plots show that this BRT has high daily passenger demand and peak loads. To cater to the demand and maintain a seamless movement of people, having a high number of buses play a critical role. Since the passenger demand and peak loading are low for Indian cities, Pune-Pimpri-Chinchwad and Ahmedabad recorded low frequencies. Besides the indicators discussed above, other indicators highlight the efficiency of a BRT. Those indicators include commercial speeds, passenger boarding per kilometre of BRT and Capital cost per kilometre. Regarding commercial speeds (kmph), Turkey and Rio de Janeiro lead this section with a commercial speed of 40 kmph. Ahmedabad BRT in India has a commercial speed of 24kmph, much better than many Asian and Latin American BRTs.

The highest passenger boarding per kilometre of BRT was achieved in Guayaquil, Ecuador, where Metrovía reported 13 passenger boardings per bus km. The lowest productivity levels were reported in Johannesburg, with two passenger boardings per bus km. Surprisingly, the passenger boardings per kilometre of BRT of Ahmedabad (5 passenger boardings/km) are in line with some of the best Latin American and Chinese BRTs. Even this relatively low level of operational productivity is still twice that observed in traditional bus systems operating in mixed traffic. External factors affect operational productivity, such as corridor density, trip length, and availability and characteristics of transport alternatives. Conversely, internal factors include the way routes are programmed (radial/diametric, short/long, local/ express), minimum headways, and occupancy levels, among others.

Total BRT capital costs are another critical indicator, including lane infrastructure, stations, buses, and technology systems such as passenger information and fare collection systems. These costs can vary from less than US$1 million per kilometre (Jinan) to US$12.5 million per kilometre (Bogota) or more. The range of costs indicates the extent of the roadway improvements needed and the relative cost of labour and materials in each country. New transit systems requiring only minor physical improvements to the roadway cost in the range of US$1–3.50 million per kilometre to implement, while major reconstruction of corridor roadways (e.g., tunnels, extensive simultaneous utility upgrades or station bypass lanes) require more capital investment: US$ 3.8–12.5 million per kilometre. These costs are one third to one-fifth of those of alternative rail technologies[22].

Chapter 4. BRT Standards and Guidelines

4.1. BRT Standard

In 2012, the Institute for Transportation and Development Policy (ITDP), in collaboration with various organizations, developed the BRT standard to ensure that BRT corridors worldwide meet a minimum quality standard and deliver consistent passenger, economic, and environmental benefits. It also functions as a technical tool to guide and encourage municipalities to consider the key features of the best BRT corridors as they move through the design process.

4.1.1. What is BRT standard?

The BRT Standard is an evaluation tool for BRT corridors based on international best practices. It is also the centrepiece of a global effort by leaders in bus rapid transit design to establish a common definition of BRT and to ensure that BRT corridors more uniformly deliver world-class passenger experiences, significant economic benefits, and positive environmental impacts. The Standard functions as a planning tool, a scoring system, and a means of achieving a common definition of BRT. Defining the essential elements of BRT provides a framework for system designers, decision-makers, and the sustainable-transport community to identify and implement high-quality BRT corridors.

4.1.2. Why was the BRT Standard created?

The BRT Standard was developed to create a common definition of bus rapid transit and recognize high-quality BRT corridors worldwide. It also functions as a technical tool to guide and encourage municipalities to consider the key features of the best BRT corridors as they move through the design process.

Despite BRT's increasing prevalence, prominence and success, many remain unaware of the characteristics of the best BRT corridors and their ability to provide levels of service more typically associated with metro and subway systems. Before introducing the BRT Standard, there was no common understanding of what constitutes BRT, which confused the concept. While new world-class BRT corridors continue to be implemented, the lack of quality control has often led to modest bus corridor improvements being branded as BRT. Additionally, the critical BRT components of planned corridors are omitted due to financial or political concerns. This has frequently resulted in a preference for rail, where BRT would be a comparable, more cost-effective, and equally elegant solution. The Standard seeks to remedy this issue by creating a common definition of BRT and its key features and an improved understanding of the resulting level of capacity, speed, and service quality from the included features.

4.1.3. Who Governs the BRT Standard?

Two committees govern the BRT Standard: The Technical Committee and the Institutional Endorsers. The Institute for Transportation and Development Policy (ITDP) currently convenes both committees. The Technical Committee of the BRT Standard is composed of globally renowned experts on BRT. This committee is a consistent source of sound technical advice concerning BRT and is the basis for establishing the credibility of the BRT Standard. The Technical Committee certifies corridors and recommends revisions to the BRT Standard as needed.

4.1.4. Overview of BRT Standard Score Card

The BRT Standard scoring system protects the BRT brand and offers recognition to high-quality BRT corridors worldwide. BRT corridors are certified as gold, silver, bronze, or basic, setting an internationally recognized standard for the current best practices for BRT. Corridors are assessed in two ways: **Design Score** and **Full Score** (Design + Operations).

4.1.5. BRT Standard Rankings

BRT experts have evaluated the elements that receive points in the BRT Standard in various contexts. Based on the points received, the BRT is categorized into four standards: Gold, Silver, Bronze and Basic, as shown in figure 4.1.

Gold-standard BRT
85 Points or above

Gold-standard BRT is consistent in almost all respects with international best practices. These corridors achieve the highest operational performance and efficiency level while providing a high quality of service. The gold level is achievable on any corridor with sufficient demand to justify BRT investments. These corridors have the greatest ability to inspire the public and other cities.

Silver-standard BRT
70–84.9 points

Silver-standard BRT includes most of the elements of international best practices and is likely to be cost-effective on any corridor with sufficient demand to justify BRT investment. These corridors achieve high operational performance and quality of service.

Bronze-standard BRT
55–69.9 points

Bronze-standard BRT solidly meets the definition of BRT and is mostly consistent with international best practices. Bronze-standard BRT has some characteristics that elevate it above the BRT basics, achieving higher operational efficiencies or quality of service than basic BRT.

Basic BRT

Basic BRT refers to a core subset of elements that the Technical Committee has deemed essential to the definition of BRT. This minimum qualification is a precondition to receiving a gold, silver, or bronze ranking.

Fig. 4.1: BRT Standard Rankings[32]

Source: ITDP

The ranking of the BRT elements resulted in consistently improved system performance and positively impacted ridership. However, being certified as gold or silver does not necessarily imply that a corridor is costly or complicated since many BRT features are low cost or even no cost. Even relatively simple systems can achieve a high score if care is given to design decisions. From Belo Horizonte, Brazil, to Yichang, China, cities built with gold-standard BRT have significantly benefited commuters, revitalized city centres, and improved air quality. The details of each element are presented in figure 4.2.

[32] ITDP. (2016). The BRT Standard – 2016. Available at: https://tinyurl.com/ybksvwf5

The BRT Standard Scorecard

This scorecard shows the criteria and point values that make up the *BRT Standard*, followed by a detailed description of each.

CATEGORY	MAX SCORE
BRT Basics (PP. 26–37)	**38 (TOTAL)**
Dedicated Right-of-Way	8
Busway Alignment	8
Off-Board Fare Collection	8
Intersection Treatments	7
Platform-level Boarding	7
Service Planning (PP. 38–44)	**19**
Multiple Routes	4
Express, Limited-Stop, and Local Service	3
Control Center	3
Located in Top Ten Corridors	2
Demand Profile	3
Hours of Operations	2
Multi-Corridor Network	2
Infrastructure (PP. 45–52)	**13**
Passing Lanes at Stations	3
Minimizing Bus Emissions	3
Stations Set Back from Intersections	3
Center Stations	2
Pavement Quality	2
Stations (PP. 53–57)	**10**
Distances Between Stations	2
Safe and Comfortable Stations	3
Number of Doors on Bus	3
Docking Bays and Sub-stops	1
Sliding Doors in BRT Stations	1

CATEGORY	MAX SCORE
Communications (PP. 58–59)	**5**
Branding	3
Passenger Information	2
Access and Integration (PP. 60–65)	**15**
Universal Access	3
Integration with Other Public Transport	3
Pedestrian Access and Safety	4
Secure Bicycle Parking	2
Bicycle Lanes	2
Bicycle-Sharing Integration	1
Operations Deductions (PP. 66–72)	**-63**
Commercial Speeds	-10
Peak Passengers per Hour per Direction (pphpd) 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 Infrastructure	-14
Low Peak Frequency	-3
Low Off-Peak Frequency	-2
Permitting Unsafe Bicycle Use	-2
Lack of Traffic Safety Data	-2
Buses Running Parallel to BRT Corridor	-6
Bus Bunching	-4

Fig. 4.2: Detailed Scorecard for BRT ranking Error! Bookmark not defined.

The auditors can use each indicator mentioned in the BRT standard scorecard to design the audit matrix.

4.2. BRT Design Guidelines for India

The first meeting of the H-8 Committee[33] of the Indian Roads Congress (IRC) on Urban Roads and Streets was held on 20th May 2015. After which, the members expressed the view that several cities in the country would require strengthening of road-based public transport and high-capacity bus transport in corridors exhibiting heavy demand for public transport. In that context, the committee decided to prepare Bus Rapid Transit guidelines. These guidelines help city authorities plan, provide and operate this mode of travel wherever deemed necessary based on existing and projected demand.

The draft report, **IRC:124-2017 "Bus Rapid Transit (BRT) Design Guidelines for Indian Cities**", was approved for printing on 14th July 2017. The following sections will discuss some of the crucial guidelines for BRT in India. However, full guidelines are available in the IRC:124-2017, BRT design guidelines document.

4.2.1. BRT Configuration and System Capacity (refer to section 3.2 of the IRC guidelines)
System capacity refers to the maximum number of people or vehicles moving in a single direction on a BRT corridor. It is important to match the system design to the required capacity, as a design with inadequate capacity can lead to delays, overcrowding, and a poor system image. Lane configuration and stations are crucial among the factors determining a BRT system's capacity. A BRT system with one lane per direction in station areas can handle about 70 regular buses an hour, or around 5,000 pphpd. This configuration is appropriate for the corridor demand in many Tier - 2 Indian cities. Above these volumes, bus congestion caused by bus docking at stations results in delays and slower commercial speeds. The capacity of a system with one lane per direction can be increased to around 9,000 pphpd by adding articulated buses or 12,000 pphpd by using bi-articulated buses.

In situations with higher passenger demand, passing lanes at stations can increase the capacity of a BRT system. The Transmilenio BRT system in Bogotá (Colombia) can carry up to 45,000 pphpd through articulated and bi-articulated buses, passing lanes at stations, and up to 60 per cent of services operating as express routes that stop only at limited locations. Another

[33] H-8 is a sub committee that deals with Urban roads, streets and transport and falls under one of the Indian Roads Congress (IRC) apex committee called HSS (Highways Specifications & Standards Committee).

system with passing lanes, the Guangzhou BRT system in China, carries 27,000 pphpd. A typical capacity of various modes is shown in figure 4.3/

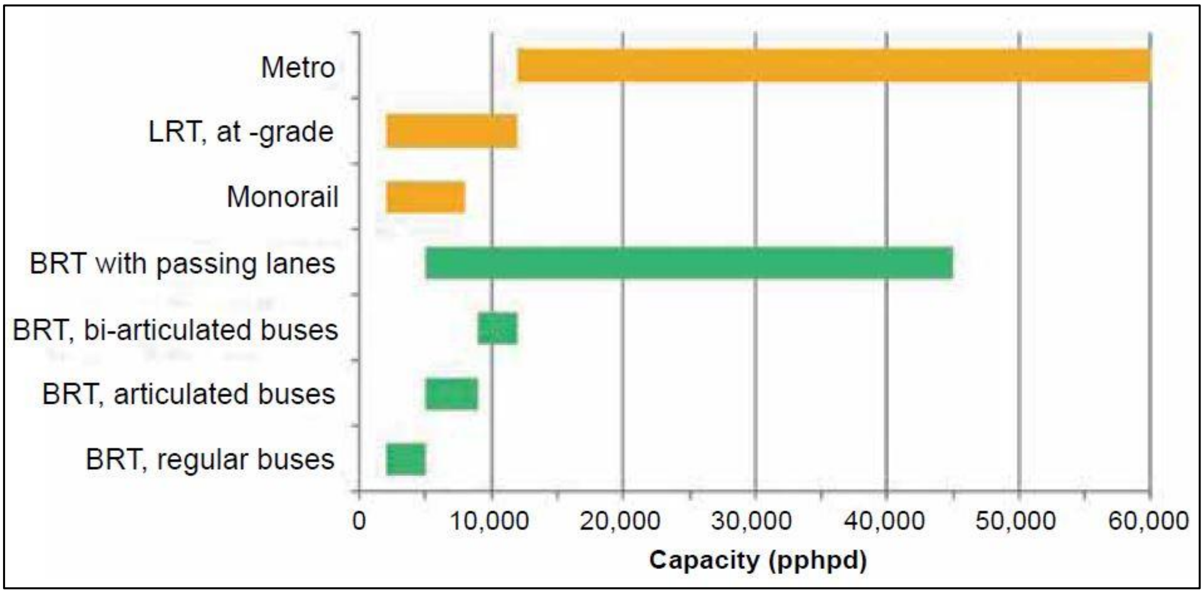

Fig. 4.3: Capacities of mass rapid transit systems[25]

A simple BRT system with one BRT lane per direction and regular 12 m buses can carry up to 5,000 passengers per hour per direction (pphpd). The capacity increases to 9,000 pphpd with articulated buses and 12,000 pphpd with bi-articulated buses. The addition of a passing lane brings a dramatic increase in capacity of up to 45,000 pphpd, far above the capacity of LRT and monorails, and is competitive with high-capacity metro systems.

4.2.2. Station Alignment

Common BRT station typologies include the following:

- A single centrally located station serving both directions of service.
- Side stations on the outer edges of a median busway, each serving a single direction of service.
- A pair of two-sided stations, each serving the same direction of travel.

A single central station serving both directions is the configuration employed in most high-performance BRTs. It has the advantages such as Optimal use of street space, Easier customer transfers between routes, Easier docking and Lower construction and maintenance costs. A recent innovation in BRT design is to develop two station buildings, each with boarding areas on both sides serving a single direction. In Lanzhou and Yichang (China), such an arrangement increased the number of vehicles that can dock at the station while maintaining a reasonable saturation level. Both of these systems utilize buses with low-entry doors on both sides.

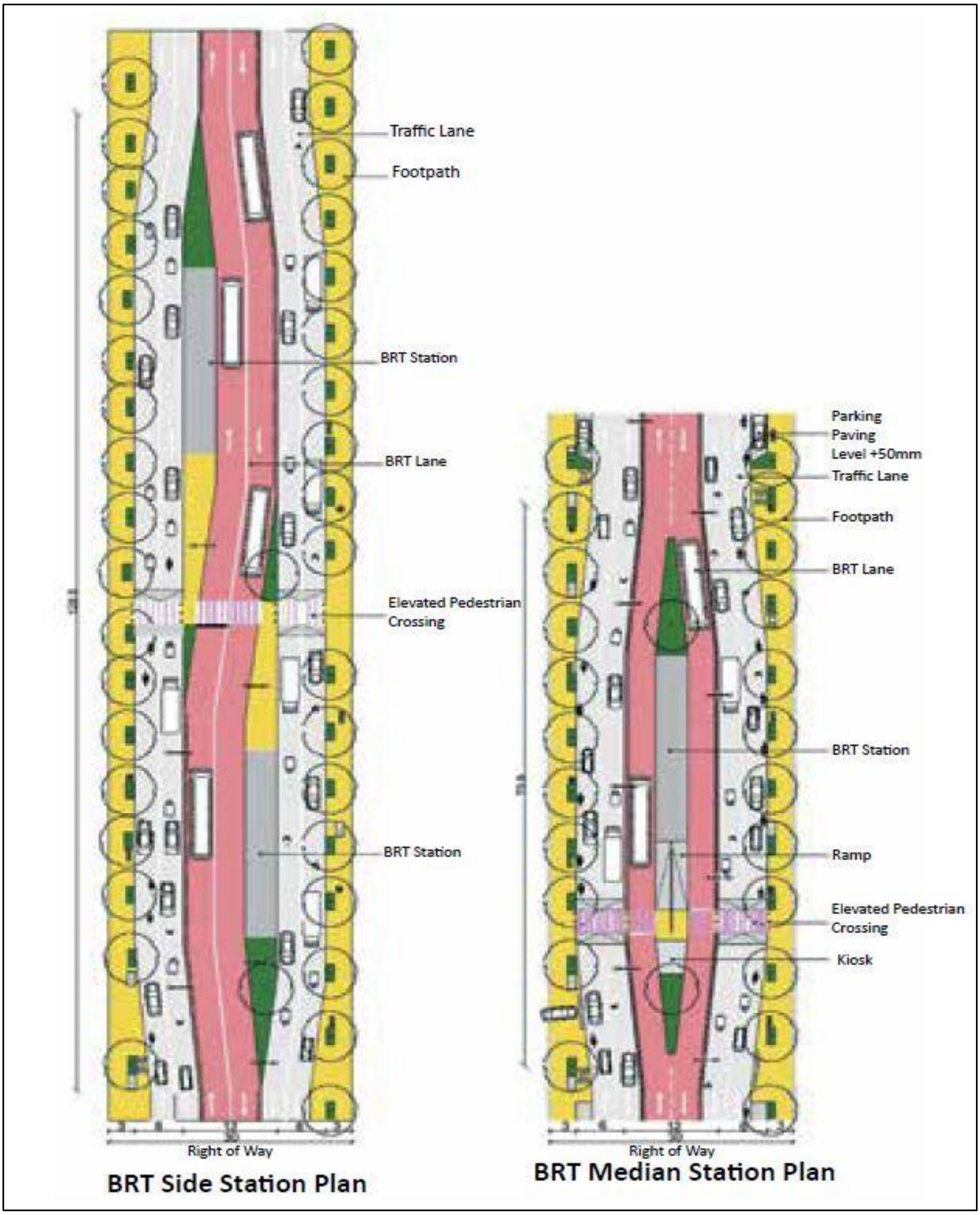

Fig. 4.4: Median stations (right) require less road space than side-aligned stations (left)

4.2.3. Bus-Station Interface

Buses and stations must be designed together to ensure that a BRT system is accessible to everyone. The station platform level should be the same as the bus floor to reduce boarding and alight time. Internal steps render a system completely unusable for persons in wheelchairs, and even small steps can cause significant delays for the elderly, disabled, or people with suitcases or strollers. To accommodate such users, BRT systems require modern buses with floor height matching the station floor's height. Reducing or eliminating the vehicle-to-platform gap is also key to customer safety and comfort. **The gap between the station and the bus should not be more than 5 cm.** To further improve safety, many BRT systems use sliding doors at stations. Doors give commuters a degree of security, protect against weather, reduce accident risks, and prevent fare evaders from entering the BRT system. BRT vehicles need to comply with the **urban bus design standards** developed by the Ministry of Housing and Urban Affairs, Government of India. (see Section 8, Vehicle Specifications).

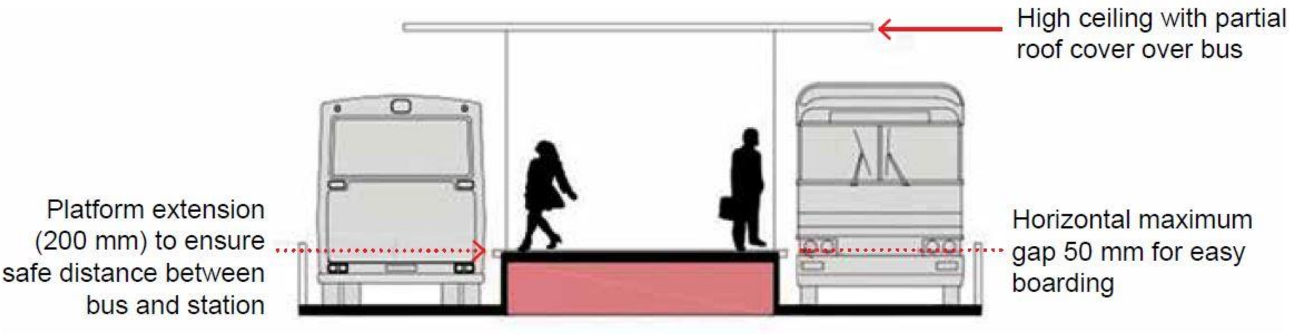

Fig. 4.5: Elements of the bus-station interface. (Platform and bus floor at the same level)

4.2.4. Distance between Stations

Stations should be placed at an average spacing of 500 m to ensure bus stops are accessible to adjoining neighbourhoods. The increased time spent walking to the stations more than offsets any gains due to higher bus speeds with greater station spacing, and the stations that are too close result in lower bus speeds. Accepting that spacing may vary from station to station depending on local conditions, systems should aim for spacing between 300 m to 800 m.

4.2.5. Corridor Design

The minimum required lane width for a BRT is 3.5 m. The corridor design guidelines are presented in figures 4.6 and 4.7.

Street element	Specifications	Minimum width (m)	Maximum width (m)
BRT lane	One-way lane	3.5	4.0
BRT lane	Two-way lane	7.0	7.5
BRT station	Median station	4.0	*
BRT lane	Passing lane at station	4.0	4.5
Buffer between BRT and mixed-traffic lanes		0.5	*
Pedestrian refuge		1.0	*
Carriageway	Mixed traffic lane (per lane for carriageways with two or more lanes per direction)	3.0	3.5
Parking	Parallel parking for cars; perpendicular parking for motor cycles and bicycles	2.0	2.5
Cycle track	One-way	2.0	*
Cycle track	Two-way	3.0	*
Footpath	Clear width	1.8	*
Footpath	Total width including furniture zone and frontage zone	3.3	*
Kerb-side bus stop for BRT direct services and other buses		2.0	*
Tree line	Next to the footpath or in the parking lane	1.0	*

* Width as per requirement

Fig. 4.6: BRT Corridor Elements: Widths

Street element	Specifications	Minimum height (mm)	Maximum height (mm)
BRT lane	BRT lane between stations	0	0
BRT lane	BRT lane at station	0	150
BRT Station	Station height	At the same height as the bus floor	
Carriageway	Tabletop crossings	100	150
Footpath		100	150
Cycle track		100	100
Bus stop	Kerb-side bus shelter	150	150

Fig. 4.7: BRT Corridor Elements: Heights (with Respect to Carriageway Level)

Refer to section 6.1 of IRC 124-2017 for more information on corridor design guidelines.

4.2.6. Right of Way (ROW) design

BRT requires wider cross-sections at stations. Elsewhere, a multi-utility zone that provides space for on-street parking and bus stops can occupy the extra 4 m of ROW that is available between stations. Walking and cycling provide last-mile connectivity to BRT stations, and space for these modes should not be compromised in station areas. BRT lanes require physical separation to prevent entry by mixed traffic. Physical delineators should be paired with adequate signage and road markings to alert personal motor vehicle users that they may not enter the lanes. A **minimum of 30 m ROW** is required to develop a BRT corridor that serves both travel directions on BRT and motor vehicles (carriageways of 2 lanes per direction). A typical BRT configuration of a 30m lane is shown in figure 4.8.

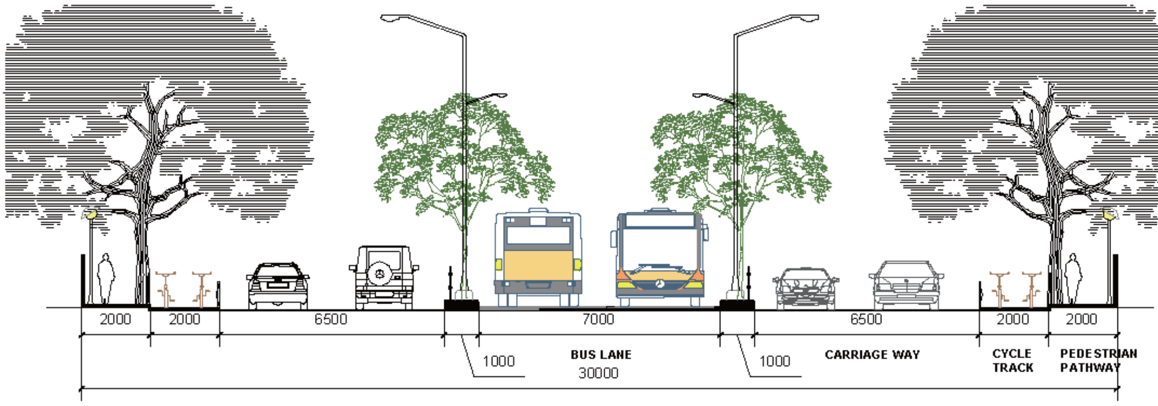

Fig. 4.8: BRT lane cross-section for 30m ROW

Source: *STI - India*

The required guidelines for various ROWs with passing and non-passing lanes are presented in tables 6A and 6B of IRC: 124-2017.

4.2.7. Universal Accessibility

Bus Rapid Transit System (BRTS) provides a dedicated corridor for quicker bus and priority vehicle movement and provides a segregated and safe corridor for pedestrians and non-motorized vehicles (NMV). The system facilitates public transport access and encourages pedestrian trips for short distances. Universal design ensures accessibility for BRT passengers and other road users and should be accessible to all irrespective of age, gender and disability. The entire BRT corridor must be designed to provide seamless pedestrian connectivity without abrupt level differences or changes in clear width. This benefits people with reduced mobility, such as people with medical conditions, families with young children, those using mobility aids and persons carrying luggage, pregnant women, etc. The design guidelines related to universal accessibility are presented in section 7 of IRC: 124-2017.

Chapter 5. BRT in India

5.1. Why does India need BRT?

A highly competitive transportation system is critical to a country's economic growth. India urbanized slowly before Independence but steadily afterwards, particularly after economic reforms in the 1990s. The urban population has increased from 11.4% in 1901 to 28.53% in 2001 and 31.16 % in 2011[34] . By 2036, urban areas are expected to house approximately 38.6% of the country's population[35]. Even though traffic in India is diverse, personalized transport vehicles such as two-wheelers (including motorcycles, scooters, and mopeds) and cars (including jeeps) account for more than 80% of the vehicle population in most major Indian cities. Because of this, cities in India face issues such as traffic congestion, longer travel times, pollution, and accidents[36] .

Similarly, in some major cities, the mode share of public transport has reduced from 60-80 per cent in 1994 to 25-35 per cent in 2018[37]. The public transportation users in India are usually called 'captive users', i.e., they use public transport because personal vehicles are unavailable or the cost of using them is too high. With the present low quality of public transport services and increasing income levels, there is a shift to private motorized vehicles. The current 'sustainable modal share' in favour of walking, non-motorized vehicles and public transport can be lost very quickly in the 'business as usual' scenario, leading to higher dependence on fossil fuels, higher GHG emissions, and increased congestion[38]. To retain the modal shares and switch from captive users to choose users of public transport in Indian cities requires the provision of efficient and utility-based public transport systems along with safe and secure support systems for non-motorized vehicles. Moreover, bus systems are flexible and can easily meet a city's changing development pattern and travel demands. Currently, buses

[34] Census of India, Ministry of Home Affairs (2011) Population Enumeration Data. Available at: https://censusindia.gov.in/2011census/population_enumeration.html.
[35] National Commission on Population (2019). Population Projections for India and States 2011-2036. Retrieved from: https://nhm.gov.in/New_Updates_2018/Report_Population_Projection_2019.pdf.
[36] Indian National Academy of Engineering (2019) Urban Transportation: Challenges and Way forward. https://www.inae.in/storage/2020/01/Urban-Transportation.pdf.
[37] Dash, D.k. (2018). Times of India - Booming Sale of cars, bikes slams brakes on public transport. Retrieved from: https://timesofindia.indiatimes.com/india/public-transports-share-of-city-trips-at-all-time-low-and-falling/articleshow/65649614.cms
[38] Tiwari, G., & Jain, D. (2010). Bus rapid transit projects in Indian cities: a status report. *Built Environment*, *36*(3), 353-362.

are the dominant mode of the public transport system in Indian cities, and there is a need to improve existing services. This has led to Bus Rapid Transit Systems (BRTs) planning in several Indian cites[38].

The initial transportation policies in India focused on increasing road capacity. The dwindling public transportation, NMT modal shares, and the increased congestion levels and emissions make it critical to shift to a sustainable transportation system rather than increasing road capacities. The Government of India announced the first National Urban Transport Policy (NUTP) in 2006, emphasising people's mobility rather than vehicles. NUTP recommended focusing on land use transport integration and prioritizing sustainable modes to ensure better management of transport problems plaguing the Indian cities. It also outlined Bus Rapid Transit System (BRTS) as a popular mode being adopted by various cities across the world[39]. In 2005, a Central Government scheme - Jawaharlal Nehru National Urban Renewal Mission (JnNURM) - offered financial assistance for urban infrastructure that extended its funding to the development of public transit systems, particularly BRT and buses.

5.2. BRT Status in India

India currently has 9 cities that adopted BRT. The Indian BRT has a daily passenger demand of 497,411 persons and an overall BRT network of 333.4 km. Table 5.1 summarizes the BRT projects in India that are dismantled, fully and partly operating, and the upcoming projects.

Table 5.1: BRT Projects in India as of 2019[39]

City	Operational Network	BRT Status	Funded By	Operating since
Pune-Pimpri-Chinchwad	22.5	Operational - Partial	JnNURM	2006
Delhi	5.8	Dismantled in 2016	State Government	2008
Ahmedabad	97	Operational	JnNURM	2009
Jaipur	20	Operational - Partial	JnNURM	2010
Rajkot	10.7	Operational	JnNURM	2012
Bhopal	24	Operational	JnNURM	2013
Indore	11	Operational	JnNURM	2013

[39] Sinha. S. (2019). BRT GOVERNANCE AND CHALLENGES – A CASE OF INDIAN CITIES. VREF Research Synthesis Project. Available at: https://tinyurl.com/y8y3jau7.

Surat	101	Operational	JnNURM	2014
Amritsar	9	Operational - Partial	JnNURM	2016
Vijayawada	10	Operational - Partial	JnNURM	2013
Hubli Dharwad	22.4	Operational	The World Bank, SUTP Project of the GoI	2018
Visakhapatnam		Under implementation	JnNURM	
Kolkata		Under implementation	JnNURM	
Naya Raipur		Under implementation	The World Bank, SUTP Project of the GoI	

The Delhi BRT project initially took its form in 1996 and, after many years implemented in 2008. Therefore, funding for Delhi BRT was provided by the state government. The subsequent BRT projects emerged through JnNURM funding as a part of NUTP. Although Ahmedabad started its full-scale operations before in 2009, Pune tested BRT in 2003. However, Ahmedabad is called the first BRT because of the scale at which it was done.

5.2.1. Critical Indicators and status of cities

The daily BRT passenger demand for Indian cities is shown in figure 5.1.

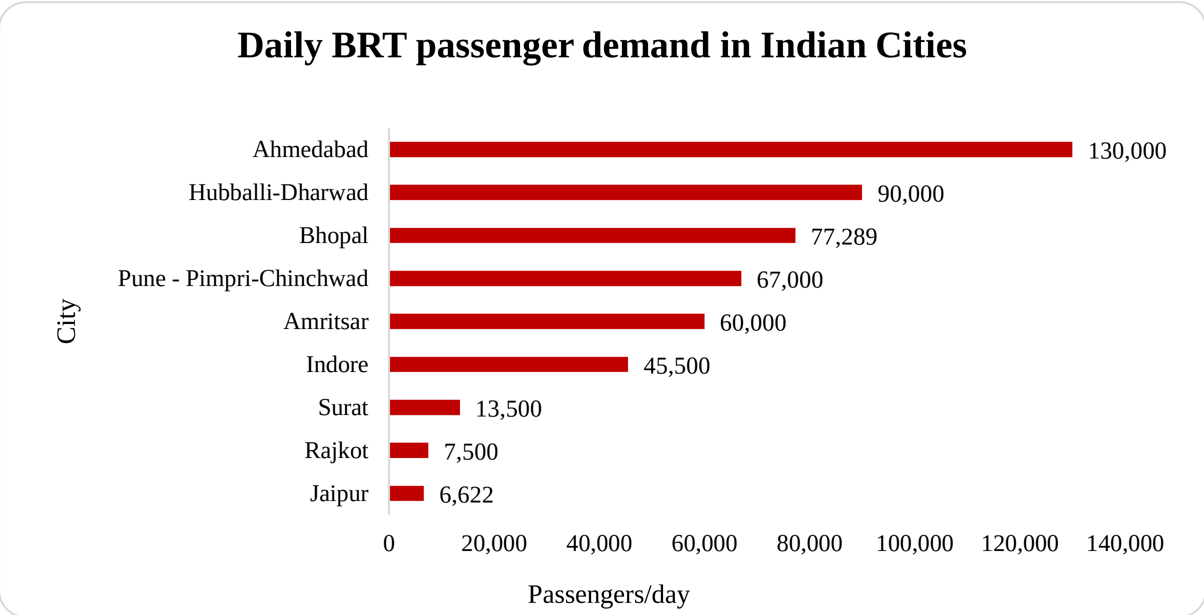

Fig. 5.1: Daily passenger demand for BRT in Indian Cities (data as of 2014)

Source: Global BRT data

With 130,000 passengers/day, Ahmedabad BRT carries the highest number of passengers in India, while Jaipur records the lowest. The BRT network length of each city is presented in figure 5.2. Surat BRT has the largest BRT network in India, followed by Ahmedabad, as seen in figure 5.2. It can be observed that Surat and Ahmedabad have extensive BRT networks. However, Surat has one of the lowest daily passenger demands.

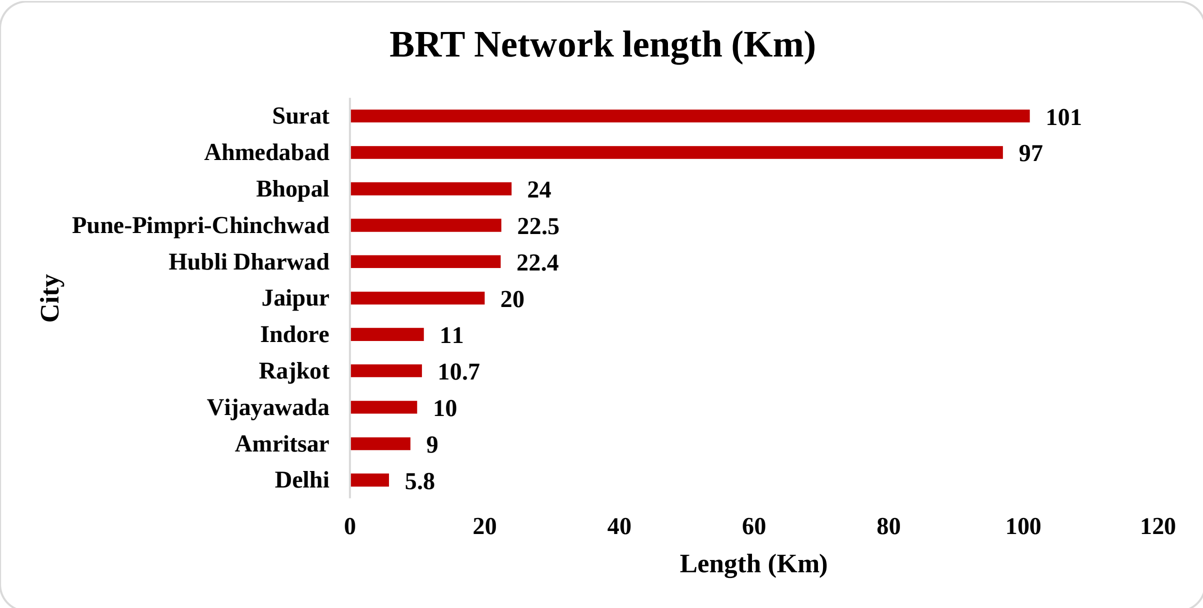

Fig. 5.2: BRT network length for Indian cities

This is primarily because the network is recently constructed, and the city plans to connect BRT with metro and other public transportation systems shortly.

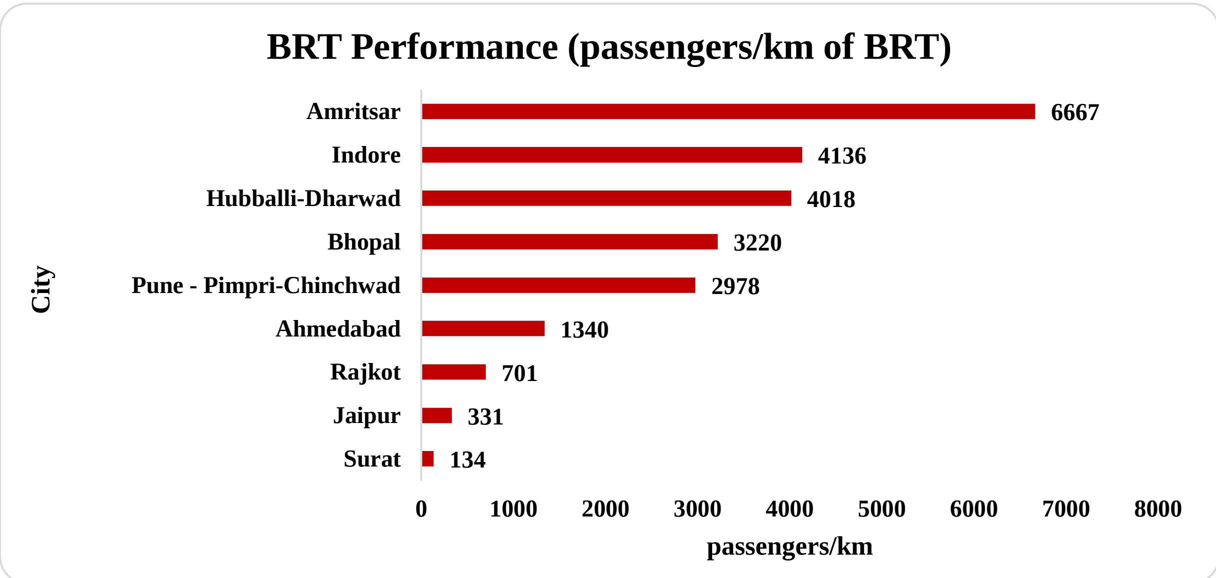

Fig. 5.3: BRT Performance (Passengers/Km)

As mentioned in chapter 3, the combination of passenger demand (demand side) and BRT network length (supply side) will give the BRT performance in passengers transported per kilometre of the BRT road network, as shown in figure 5.3. Despite having the largest road network, Surat showed the lowest performance for the reasons discussed earlier. Amritsar has the 5th largest passenger demand and the lowest running BRT network, making it the best performing BRT for passengers transported per kilometre. Another important indicator to measure performance is frequency. A comparison of peak frequency, i.e., the number of buses during peak hours, is presented in figure 5.4.

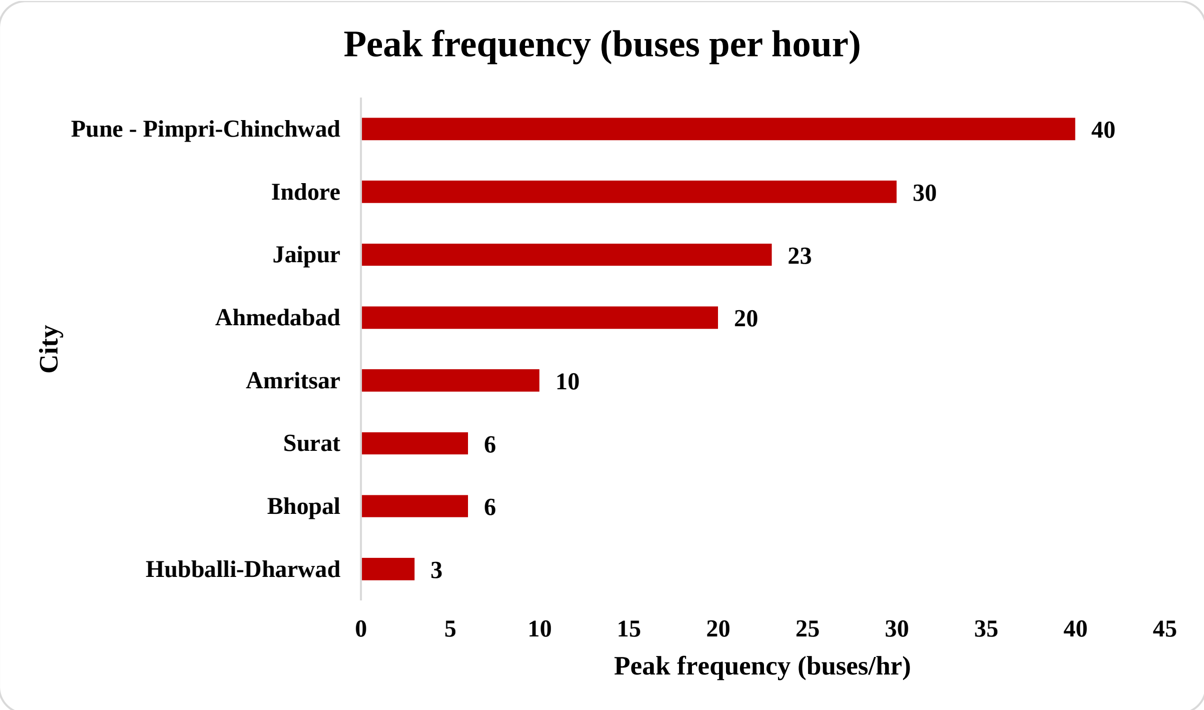

Fig. 5.4: Peak frequency (buses/ hour) during peak hours

A high-frequency public transportation system reduces travel times, making it attractive. The Pune BRT has the highest frequency with 40 buses/hr and the lowest being Hubbali-Dharwad with 3 buses per hour, as seen in figure 5.4,

5.2.2. Type of BRT

As mentioned in section 2.3, there are four road-based public transportation systems: Kerbside lanes, Busways, Closed and Hybrid BRT.

Table 5.2: Type of BRT in Indian Cities[38]

City	BRT Type		
	Open (Kerbside & Busways)	Closed	Hybrid
Delhi	✓		
Ahmedabad		✓	
Pune			✓
Surat		✓	
Jaipur			✓
Indore	✓		
Bhopal			✓
Visakhapatnam		✓	
Vijayawada	✓		
Rajkot		✓	

In India, many cities have planned for an open BRT system, as seen in table 5.2. Although open BRT has the flexibility of bus movement at the intersections, it is also one of the primary reasons for accidents. In many cities, the public is strongly opposing BRT due to these very reasons for increasing accidents. Hybrid BRT systems have proven to be much more useful than closed BRTs, and some high-capacity BRT, such as Guangzhou BRT, are hybrid BRT.

5.2.3. Bus Lanes

The width of bus lanes is either 3.3 m or 3.5 m, with 3.5 and 3.75 m at bus stops. Different means have been used to segregate the bus lanes from the main carriageway. In Delhi, Indore and Surat, kerbs are used, while railings are used in the other cities. In Delhi, fences have been used only at intersections to identify exclusive bus lanes from mixed traffic situations. The appropriate use can assure the safe movement of buses in bus lanes of segregation methods. Rumble strips are used in Delhi, Pune, and Rajkot, while lane markings are used in Ahmedabad, Jaipur, and Bhopal. Wide medians are planned to be used in Surat and Vijayawada. A summary of the bus lanes and their specifications is presented in table 5.3.

Table 5.3: Bus lanes and their specifications[38]

City	Lane width	Tools to segregate bus lane from Carriageway		Tools to segregate two bus lanes		
		Only Kerb	Railing	Rumble strip	Lane marking	Divider
Delhi	3.3m	Yes		Yes		
Ahmedabad	3.5m		Yes		Yes	
Pune	3.3m		Yes	Yes		
Surat	3.5m	Yes				Yes
Jaipur	3.3m		Yes		Yes	
Indore	3.3m	Yes				
Bhopal	3.3m		Yes		Yes	
Visakhapatnam	3.5m					
Vijayawada	3.5m		Yes			Yes
Rajkot	3.5m		Yes	Yes		

5.2.4. Bus Stops

Two types of bus stop designs are possible in the case of median bus lanes: staggered or island platforms.

Fig. 5.5: Staggered Bus stop

Fig. 5.6: Island Bus stop

Ahmedabad and Surat's ten cities have planned for island platforms, while in Jaipur, both types of bus stops are proposed. The average distance between bus stops in all the cities is 500 m except in Ahmedabad and Vijayawada (table 5.4).

Table 5.4: Bus stop details[38]

City	Staggered	Island	Bus Stops			
			Before Junction	Far-side of Junction	Overtaking lane at Bus stop	Average distance between bus stops (m)
Delhi	Yes		Yes			500
Ahmedabad		Yes		Yes	Yes	800
Pune	Yes		Yes			500
Surat		Yes		Yes		600
Jaipur		Yes	Yes		Yes	500
Indore	Yes		Yes		Yes	500
Bhopal	Yes		Yes			600
Visakhapatnam	Yes		Yes		Yes	700
Vijayawada	Yes		Yes			750
Rajkot		Yes		Yes		600

Staggered platforms are planned at the approach arms of the intersections, thus using the red phase of traffic signals for boarding and alighting. This enhances the level of service provided by the system. Wherever intersection spacing is more and points of significant boarding/ alighting occur between intersections, provision has also been made for mid-block bus stops.

5.2.5. Integration of BRT with Other Modes of Transport

Integration of BRT with other existing modes of transport is essential to provide comfortable access and egress to and from the system. This can be achieved by providing safe and secure infrastructure for NMT and parking for cycles, autorickshaws and private motorized vehicles[38].

Walking

All bus users are pedestrians either during access or egress or for both trips. The effectiveness of the system thus depends on the safety of pedestrians on-road and the comfort provided for accessing the bus service. Except in Ahmedabad, continuous footpaths have been planned for the safe movement of pedestrians along the corridor, which is separate from the NMT lanes. In

Bhopal, where the right of way (ROW) is less than 20 m, a combined 3 m wide space has been provided for pedestrians and cyclists. Zebra crossings with pedestrian-activated traffic signals have been provided in all the cities, both at junctions and mid-blocks where bus stops have been planned. In Delhi, raised zebra crossings have been provided on free left turns and minor access roads joining the main corridor. Grade-separated facilities have been planned in Ahmedabad and Pune at mid-block bus stops where demand is high. Surat's primary carriageway has been elevated to provide a grade crossing for pedestrians. Dedicated bus lanes in all the cities are planned on the central lane, thereby reducing the crossing distance for pedestrians using the bus on the corridor and conflicts between buses and slow-moving vehicles (non-motorized modes like pedestrians and cyclists). In Delhi, raised ramps have been provided to reduce conflicts between pedestrians and motorized vehicles at access points to properties.

Cycles and Cycle Rickshaws

Cycle tracks have been planned based on the availability of ROW. In Delhi, Indore and Rajkot, continuous cycle tracks and cycle lanes are planned on either side of the corridor. The width of these tracks ranges from 1.8 m to 2.7 m. Signalized crossings have been created by providing cycle boxes at intersections to allow cycles to wait for the green phase of the signal. Bicycle parking has been planned along the corridor near bus stops and junctions in Delhi, Pune, Jaipur and Indore. On the Delhi-BRT corridor, parking for cycles has been provided along the NMT lane, which is not more than 100 m away from the intersections, and there is provision for rent and ride facilities at some stations.

Intermediate Paratransit (Three-Wheelers)

Auto-rickshaws free parking facilities have been planned along the corridor near bus stops and junctions in Delhi, Ahmedabad, Pune, Jaipur, Indore, Vijayawada and Rajkot. This increases the all over catchment area of the BRT system.

Motorized Wheelers

Paid on-street parking has been planned in Ahmedabad, Jaipur, Indore, and Rajkot. In Vijayawada, paid off-street has been planned for 50–200 equivalent car spaces for every 1 km of the BRT corridor. In Delhi, apart from off-street parking, stopping bays for both cars and heavy vehicles have been planned along the main carriageway.

5.3. BRT and Other Mass Transport Policies in India

5.3.1. Jawaharlal Nehru National Urban Renewal Mission (JNNURM), 2005 and National Urban Transport Policy (NUTP), 2006

The Jawaharlal Nehru Urban Renewal Mission (JNNURM) was set up in 2005, and the National Urban Transport Policy (NUTP) in 2006 under the Ministry of Urban Development to create sustainable transportation with a focus on improving the public transportation system across major cities[40]. Under this mission, the central government provided the cities with funds to modernize the existing urban infrastructure and manage the local urban issues successfully. Under these policies' the cities should submit a comprehensive mobility plan (CMP) to secure funding from the central government. Adopting a partnership approach, depending on the size of the cities, the national government funded 35% to 50% of the project cost. The state governments share 15% to 20% of the project, and the local governments share the balance of 50% to 20% of the total investment. The local governments could mobilise their own resources or through other market sources[41]. Most of the BRT projects in India are implemented under the NUTP (2006) policy with funding from JnNURM (2005). A total of Rs. 572490 million (at Rs 1180 million per km) has been sanctioned from the JnNURM since August 2006 for a total network of 483 km[41]. Further, NUTP advocates establishing the Unified Metropolitan Transport Authority (UMTA) in cities with over a million inhabitants[42].

5.3.2. National Electric Mobility Mission Plan (NEMMP) 2013

The National Electric Mobility Mission Plan (NEMMP) was adopted in 2013, with the target year as 2020. This plan highlights the significance of adopting electric vehicles (EVs). The NEMMP presented a framework for the early adoption of EVs and hybrid vehicles. Further, the Faster Adoption and Manufacturing of Hybrid and EV (FAME) was introduced in 2015 to reduce the initial purchasing costs and early adoption of EVs and hybrid vehicles. Under phase I of the FAME India scheme, 425 e-buses were sanctioned and delivered. Currently, under phase II of the FAME India scheme, 5595 e-buses are allocated across 65 cities, and 3660 buses are approved for order after a successful tender process[43]. However, there is no clear framework

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[40] Baindur D (2011) Planning Sustainable Urban Transport System–Case Study of Bangalore Metropolitan Region. J Econ Poli Res 7(1).

[41] Swamy, H. S., & Sinha, S. (2014). Urban Transport Developments in India under NUTP and JnNURM. *John Diandas Memorial Lectures, Sri Lanka*.

[42] ITF (2021) Decarbonising India's transport system: charting the way forward. International Transport Forum Policy Papers, No. 88, OECD Publishing, Paris

[43] Anumita Roychowdhury and Sayan Roy 2021, *Electric Bus: Towards Zero-Emission Commuting*, Centre for Science and Environment, New Delhi.

about how many e-buses are allocated to BRT in cities. It is observed that Ahmedabad BRT is the only BRT operating with 11 e-buses out of 50 as of March 2021[43]. Recently, Ahmedabad BRT procured 60 more e-buses from TATA Motors[44].

Similarly, other initiatives, such as smart cities mission-2015, Green Urban Mobility Scheme – 2017 and National Policy on Transit Oriented Development-2017, highlight BRT's significance in improving public transportation. However, transport systems such as MRT such as the bus rapid transit, the light rail transit, the monorail and several other guided modes of transport and issues of transport planning, multi-modal integration, safety, tariff, and financing are not covered under any act. The state and local urban bodies usually develop the Detailed Project Report (DPR), and the funding is generally secured on a first-come, first-serve basis.

5.4. Key Observations from Indian BRT systems

In the wake of growing traffic, increased congestion levels and emissions, the Government of India started implementing BRT across many cities in India. Delhi was the first city to implement the BRT with state funding. Although the network was short as compared to other BRT, it did not operate for long. Ever since the BRT corridor opened for all buses operating along the corridor, it has provided them with faster travel time due to the dedicated lane. However, this 5.8 km pilot corridor was dismantled after eight years of operation (2008-2016), being criticised mainly for the inconvenience caused to private transport modes owing to the reduction of their road space and increase in traffic congestion.

Additionally, there were reports of increasing accidents, bus breakdowns, and confusion about bus stops and the process, which increased the pressure from the public and eventually led to its closure[45]. Amongst the issues, accidents and reduction in road space were found to be the primary reason, as seen in Ahmedabad and Pune, which led to strong opposition from the public[46]. Table 5.5 presents the operational statistics of Ahmedabad BRT.

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[44] Business Today. (2021). Tata Motors delivers 60 Ultra Urban electric buses for Ahmedabad's BRTS. Business Today. Retrieved from: https://www.businesstoday.in/latest/story/tata-motors-delivers-60-ultra-urban-electric-buses-for-ahmedabads-brts-314399-2021-12-03.

[45] Misra. T. (2016). Bloomberg: Why Did Bus Rapid Transit Go Bust in Delhi? Retrieved from: https://tinyurl.com/y9x5z2yb

[46] Jha. R. (2020). 'Have Indian cities bid farewell to the Bus Rapid Transit System?' Observer Research Foundation. Retrieved from: https://tinyurl.com/y8buphmt

Table 5.5: Operational Statistics of Ahmedabad BRT[39]

Item	Year							
	2009	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Network length (km)	13	39	45	52	80	96	97	97
No. of stations	20	61	67	80	124	149	152	152
No. of routes	1	4	5	7	9	12	12	12
Fleet size (buses)	24	60	113	118	135	225	225	230
Buses on road	18	56	103	112	128	209	207	211
Peak headway (min)	5	3–5	4–8	5–8	3–5	3–5	3–5	3–7
Off-peak headway (min)	8–10	5–8	5–10	6–12	5–8	8–10	8–10	8–12
Avg. daily Passengers ('000)	20.2	102.2	136	109.7	113.8	121.2	126.6	130.4
Avg. daily vehicle km ('000)	3.6	14.3	20.5	22.5	32.9	48.6	48.7	48.2
Average daily cost INR Mn	71.5	269.2	374.3	533.2	764.3	985	1178.4	1411.4*
Average daily earning INR Mn	25.7	206.8	324.6	462.3	566.3	732.6	na	869.5*
Operating Ratio	2.78	1.3	1.15	1.15	1.35	1.34		1.62

It can be seen that, despite the improving infrastructure, ridership and costs, the Ahmedabad BRT is still running under losses. Table 5.6 shows the operational statistics of Jaipur.

Table 5.6: Operational Statistics of Jaipur[39]

Item	Year		
	2016	2017*	2018
Fleet size (buses)	407	407	503
Buses on road	407	407	280
Avg. daily Passengers (in mn)	0.149	0.88	0.139
Avg. daily vehicle km per bus on road	212	201	217
Average cost INR/month (in mn)	91.8	NA	87.2
Average earning INR/day (in mn)	48.8	NA	47.6
Operating Ratio	1.88	1.75	1.83

Similar to Ahmedabad BRT, Jaipur BRT is also running with losses, despite having a hybrid system. Due to the reduction in operating bus fleet, the costs have been reduced; the operating ratio is still similar across the years. In the case of Indore BRT, the opposite trend is observed. Table 5.7 shows the statistics of Indore BRT.

Table 5.7: Operational Statistics of Indore BRT

Item	Year				
	2013	**2014**	**2015**	**2016**	**2017**
length (km)	11.3	11.3	11.3+21.2 *	11.3+21.2 *	11.3+21.2 *
No. of stations	21	21	21+30*	21+30*	21+30*
No. of Routes	1	1	3	4	5
Fleet size	18	28+8	28+10*	28+13*	28+13*
Buses on road	18	28	28	28	28
Peak headway (min)	6	3	2	2	2
Off peak headway (min)	8	5	5	5	5
Avg. daily passengers	20986	31370	40426	43543	47873
Avg. daily vehicle kilometres (km)	1863	4565	7222	7615	7366
Avg. daily cost (inr)	162000	351378	402240	470669	510440
Avg. daily earning (inr)	86299	227472	505305	576800	636040
Operating ratio	1.88	1.54	0.8	0.82	0.8

Although Indore BRT operated with losses in 2013, it gained profits over the years of service. It can be seen that, despite maintaining the same fleet size from 2015 to 2017, the daily passenger demand has increased, vehicle kilometres travelled reduced, and profits profit ratio has increased.

5.5. Where did it go wrong?

Although BRT in India started with the hope of reducing the transportation problems, not everyone reached their desired targets. The primary reasons for the success/failure of Indian BRT are highlighted below.

- The absence of regulatory policies for private vehicles is one of the primary reasons of BRTs fail to attract passengers. Despite providing the public transportation infrastructure, a significant modal shift to BRT cannot be acquired unless the private vehicle growth is regulated.
- Most footpaths and cycling infrastructure provided at the BRT stations are often encroached, forcing pedestrians to use the road to walk. Besides the impending dangers, reduced walking speeds increase the overall travel times, making BRT look unattractive.
- The lack of proper connectivity to the high-density areas and low-income neighbourhoods attracts more passengers. Although Ahmedabad BRT is claimed to be the best India BRT, it has failed to reach its targets. Despite having a long BRT network, the high-density areas are not well-connected with BRT. The low-income groups were not benefitted from the BRT system. Since the low-income groups primarily depend on public transportation, high fares and poor connectivity did not help them choose BRT for their commute.
- Communication and information outreach plays a critical role in adopting BRT. In cities such as Delhi, Ahmedabad and Pune, there was a lack of communication between the authorities and the public. This led to the people being unaware and confused about using the infrastructure and the BRT services. However, Indore has well-informed its public about the BRT project and pilot tested it without charging commuters. This key element attracted more ridership to inform BRT, making it a successful BRT.
- Setting up benchmarks, frequent surveys and restructuring the operations based on the feedback to reach the benchmarks have proven beneficial, as seen from section 2.4.2. However, a similar situation is not observed in Indian BRT. Despite multiple appeals to the local authorities about the inefficient BRT infrastructure in Pune, no improvements were made.

- Accidents were other reasons for solid opposition from the public about BRT. The lack of lane discipline and encroachment of BRT lanes resulted in many accidents. Since a lane was allocated for BRT, the existing road space shrunk, and the congestion levels increased, leading to public outcry. Improper design at the intersections was leading to collisions on turns.
- Lack of proper funding also played a critical role in under success of BRT. While cities that went for the BRTS were initially provided capital to invest in new buses by the GoI, this introductory central assistance no longer exists. ULBs are now on their own and are finding replacing ageing buses and adding new ones for increased population an uphill task. With inadequate and run-down fleets, the bus services in many BRTS cities have been caught up in a vicious circle of smaller fleets, fewer passengers, and more significant losses. In cities where the states are running bus services, the situation does not appear rosier since states are also financially struggling, and BRTS does not seem to be a priority[46].
- Less attention has been paid to BRT's since the emergence of metro services. Apart from Kolkata and Delhi that began metro construction before the arrival of BRTS, Bengaluru, Jaipur, Ahmedabad, Pune, Pimpri Chinchwad, Indore, Bhopal, Surat, and Rajkot — all lined up to go in for metro. States were equally enthused, and so was the GoI. It extended INR 74,400 crores for metros, and state governments extended their support. Quite visibly, BRT seems to have been overshadowed by the metro[46].

The public transportation system is a discretionary function of the local authorities. More emphasis on public transport has been predominantly driven either through the presence of funding schemes or an administrative/political champion. Over time cities realized the need for strengthening public transport systems to meet their increasing transport challenges. With the Central Government's new alternative analysis framework, the smaller cities' difficulties in meeting metro operational deficits and BRT's positive experiences can make BRT affordable alternative public transport. At the same time, improving city bus services and integrating these with BRT, managing competition from informal modes, and implementing 'push measures' is necessary for achieving mode shift in favour of public transport[39].

Summary

This report collates information on Bus Rapid Transit systems worldwide, focusing on Indian BRT.

The first chapter introduces the basic challenges such as urbanization, vehicular growth, congestion and pollution at the global and Indian levels. The significance of the transportation sector in solving some of these challenges is discussed, followed by introducing BRT as one of the potential solutions. The second chapter discusses the BRT in detail. The benefits achieved through BRT and the best practices with case studies are discussed. The third chapter presents the global trends in BRT. This chapter compares critical indicators across various regions, countries and cities to understand the best performing BRTs worldwide. The fourth chapter presents the BRT standards adopted globally and the guidelines adopted in India. Chapter 5 focuses on BRT in India. Some critical indicators are compared across various BRT cities in India. An in-depth discussion about the BRT. The policies that advocate for Indian BRT and the reasons for the success/failure of BRTs are also discussed.

Like many other studies, this report finds that Latin American countries lead the BRT system worldwide, followed by China. The BRT network length, peak hour and daily demand of Latin American countries and China are significantly large than many other countries, including the developed economies. Since the early 2000s, the BRT network has increased, and China has extensively built the BRT infrastructure. BRT is thriving in these countries primarily because of its holistic planning approach, setting benchmarks and frequently upgrading based on the feedback from the public, strong stakeholder engagement, integration of BRT with other public transport modes and utilization of innovative financing mechanisms. Because of these reasons, most of China and Latin American cities are gold standard BRTs operating at high capacities. Despite developed economies such as France, the UK and the US having BRT, the ridership is significantly low compared to developing economies because of their car dependency. The low frequency and poor connectivity do not attract BRT passengers.

India also adopted BRT to solve the issues of congestion and pollution. Pune was India's first city to test BRT, followed by Delhi and Ahmedabad. The BRT system was implemented under the National Urban Transport Policy (2006) with funding from JnNURM. Currently, India has 11 cities with BRT and 3 are in progress. Despite being the second-largest population globally, and most people depend on public transportation, BRT ridership in India is significantly low than in Latin American countries and China. The BRT network levels are in the middle spectrum of the top 15 countries. There are multiple reasons why BRT did not achieve its desired targets. Some include opposition from the public because of the increased accidents. The other modes of transport were using the BRT lanes, which led to accidents.

Further, the reduced road space due to allocating a lane to BRT increased congestion, and the public opposed it. Most cities have poor BRT infrastructure for pedestrians and cyclists, and despite the people voicing their opinions, authorities made no improvements. The poor connectivity also added to the low ridership. Other than Pune, most BRT networks are developed on easy construct corridors, and less attention was paid to peak hour demand or connectivity to the low-income-neighbourhoods. Since the inception of metro services, most of the transport-related funding has been allocated to the metro by side-lining BRT. This added pressure on the local urban bodies managing the BRT to scramble for funds to increase the fleet and network size to keep the services running.

Based on these observations, the following recommendations are proposed.

- BRT planning should be holistic, as seen in China, Brazil, Colombia, and other Latin American countries. Most of India's BRTs run on short stretches with a single corridor. An extensive network with high-frequency bus stops and multi-modal connectivity is crucial in attracting more passengers to BRT. The primary goal of the commuter is to reach the destination in the shortest possible time. Therefore, shorter BRT routes eventually lead to delays and increased travel times due to more mode interchanges, making BRT a non-feasible option.
- Multiple policies implemented together have more impact than a single policy[47]. Therefore, besides BRT implementation, the government should also implement regulatory policies to reduce private vehicle usage. Policies such as increasing vehicle taxation and congestion pricing have successfully reduced personal vehicle usage in Singapore and the UK. A combination of private vehicle regulatory policies and public transport encouragement policies such as BRT will lead to a modal shift towards BRT.

[47] Verma, A., Harsha, V., & Subramanian, G. H. (2021). Evolution of Urban Transportation Policies in India: A Review and Analysis. *Transportation in Developing Economies*, *7*(2), 1-15.

- Proper separation of BRT lanes with barriers from mixed traffic reduces travel delays and accidents. The intersection should be designed to have fewer conflict points, as mentioned in the IRC: 124-2017. Additionally, strong penalties on violators should be enforced to reduce lane violations.
- BRT's construction and operational costs are significantly less than metro while having similar passengers per hour per direction. Therefore, rather than focusing more on the metro, efforts should be directed to BRT. Further, BRT and metro networks should be connected with other feeder services to increase ridership.
- The concerned authorities should frequently conduct surveys about the BRT services from the public and use the feedback to upgrade the operations and network, as is done in Istanbul BRT. The survey information can also be used to understand which high demand areas income-group neighbourhoods are being neglected.
- Hybrid systems are more efficient than closed and open BRT. Although there are hybrid BRT in India, such as Jaipur, it has failed due to a lack of funding. Other BRTs with partial hybrid BRT should be converted to full hybrid BRT.

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