Innovations in Bus Rapid Transit (BRT) in Brazil and China

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Abstract

Currently, Brazil and China are at the forefront with the largest Bus Rapid Transit (BRT) networks globally. Since the 1970s, Brazil has been building its expertise, spearheading the creation of an industry focused on designing and manufacturing vehicles specifically for the BRT system. These vehicles have undergone continuous innovation in both Brazil and China. This development has occurred alongside enhancements in BRT stations and the adoption of inclusive urban designs, which have transformed the public spaces surrounding the terminals. This transformation has not only introduced new methodologies in urban design but has also elevated the architectural significance of terminal buildings. The innovations span from vehicle and terminal architecture design to specific urban planning, all augmented by the advent of cutting-edge technologies. These technologies facilitate intelligent traffic management within BRT corridors and automate fare collection, marking a significant step toward transforming transportation into a smarter system. This study aims to compare the significant advancements made in Brazil and China, focusing on the synergy between vehicle design, terminal architecture, accessible urban planning, and smart management and ticketing systems. The goal is to underscore how these advancements are propelling public transport towards greater efficiency, sustainability, and intelligence.

Keywords
Bus Rapid Transit, Smart transportation systems, Green transportation, Innovation in urban transportation, Transport planning, Planning in high-density urban contexts

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THE ORIGINS OF THE BUS RAPID TRANSIT (BRT) SYSTEM

Curitiba's transportation and urban planning innovations began in the mid-1960s, marking a significant departure from traditional modernist urbanism which emphasised private automobile use. Instead, Curitiba prioritised public transport, establishing itself as a pioneer in this field with several key initiatives that have garnered international acclaim. One of the most notable innovations was the introduction of the Bus Rapid Transit (BRT) system. This system, characterised by dedicated bus lanes (also known as BRT corridors), facilitated efficient and rapid public transport, effectively reducing traffic congestion and promoting the use of public transit over private cars. By closing central streets to private vehicles and dedicating them to pedestrians and buses, Curitiba created a more accessible and environmentally friendly urban core.

Curitiba's urban planning also emphasised the integration of land use and transportation. The city's master plan incorporated zoning laws that supported mixed-use development, ensuring that residential, commercial, and industrial areas were well-connected by the BRT system. This approach not only improved mobility but also enhanced the quality of urban life by reducing travel times and promoting sustainable urban growth. The city's success can be attributed to several factors, including strong political leadership, innovative thinking, pragmatic decision-making, technocratic governance, and the continuity of its policies[1]. These elements helped maintain the effectiveness and relevance of Curitiba's urban planning initiatives over the decades.

Despite the global influence and the spread of modern planning paradigms, Curitiba has retained some traditional elements in its planning approach. The focus on detailed vehicle movement analysis and the involvement of engineers in planning roles highlight a more positivist and infrastructure-centred perspective[2]. However, these characteristics have allowed Curitiba to maintain a robust and effective transportation system, even as new integrative planning trends emerge. Overall, Curitiba's innovative approach to transportation and urban planning has set a benchmark for cities worldwide, demonstrating the potential of prioritising public transit and integrated land use to create sustainable and livable urban environments.

THE CREATION OF CURITIBA'S BRT SYSTEM AND THE TRANSFER OF KNOW-HOW TO BOGOTÁ, COLOMBIA

Three interventions transformed urban transportation in Curitiba: the Express Line buses in 1974, the Direct Line in 1991, and the Biarticulated BRT Express Line in 1992. The Express Line was inspired by the Preliminary Study of the Metro System in 1969, which involved research by professionals and analysis of various systems worldwide. The need for an efficient transportation system to consolidate the 1965 master plan and financial limitations led to the adaptation of a metro system into a road system, which remains one of the main systems today. The first measure was the implementation of exclusive lanes, which were later used by the new bus model.

Fig. 1 and 2. The Curitiba BRT.

In 1991, the Direct Line emerged, inspired by the “Network: The Tram as a Solution” plan of 1981. This plan was a response to the oil crisis and proposed linking the city’s main structural axes, south and north, with a system of light and electric rail vehicles. Thus, the Ligeirinho bus was created, functioning like a metro on wheels. Boarding was done in tube-shaped cabins with prepayment, increasing operational speed from 20 km/h to 32 km/h and reducing costs by 18%.

The Biarticulated Express Line was created in 1992 to meet the growing passenger demand, using existing lanes with higher capacity and level boarding stations. This new system maintained features such as exclusive lanes, user communication, priority traffic lights, and universal accessibility. The biarticulated vehicle could transport up to 270 passengers, with separate entrances and exits and a sensor-based opening system at the stations.

The interventions in Curitiba’s urban transportation system (Figure 1 and 2) represent a milestone in innovation and urban planning. The pioneering solutions, such as the Express Line, Direct Line, and Biarticulated Express Line, demonstrate how adapting traditional concepts can lead to significant improvements in urban mobility. These interventions not only improved public transportation efficiency but also promoted urban integration and sustainability. Curitiba’s BRT system shows that it is possible to create effective and economical solutions for public transportation, even in the face of financial limitations. Collaboration between various sectors and the continuous pursuit of innovation were fundamental to the success of these projects.

An example of this collaboration is the relationship between the bus manufacturer Volvo[3] and the Curitiba city council. From the beginning, Volvo played a crucial role in developing specific vehicles to meet the system’s needs, such as articulated buses and same-level door boarding, which are essential for its efficient operation. The partnership between Volvo and Curitiba is a prime example of a successful public-private partnership. The city benefits from Volvo’s expertise and innovation, while the manufacturer gains an important testing ground for its urban transport technologies.

Furthermore, Curitiba’s experience highlights the importance of considering not only transportation efficiency but also the user experience and integration with urban space. The practices adopted in the city demonstrate that a holistic urban planning approach, which takes into account pedestrians and connectivity between different modes of transport, is essential for the sustainable development of cities.

The team that developed the BRT system in Curitiba later played a crucial role in the development of the TransMilenio system in Bogotá. Curitiba's BRT, established in the 1970s under the guidance of architect and urban planner Jaime Lerner, became a model for efficient and cost-effective urban transit solutions. Its success attracted global attention, showcasing how dedicated lanes and rapid bus services could transform city transportation.

In the late 1990s, Bogotá sought to address its growing traffic congestion and inefficiencies in public transport. Inspired by Curitiba's achievements, the city invited the same team of experts to help design and implement a similar system. The TransMilenio, launched in 2000, was tailored to Bogotá's unique needs, incorporating lessons learned from Curitiba. Today, both systems are celebrated for their innovative approaches, significantly improving urban mobility and serving as blueprints for other cities worldwide looking to enhance their public transportation infrastructure.

PRELIMINARY CONSIDERATIONS ON THIS STUDY

It is important to clarify that this is an initial study conducted by a team of Brazilian and Chinese researchers in urban and regional planning. The aim is to better understand the potential of the BRT system in urban development processes and how its implementation can enhance the quality of urban projects and public, walkable spaces around the BRT system.

We are also interested in observing the long-term impact of the system on land use and occupancy, noting significant improvements in environmental quality and urban landscape. As an initial study, we have relied on data collected from international research institutes[4] that advocate for the BRT brand and standards. During the process, we found that some of these sources contained outdated information that needs to be updated in the next stages of our collaborative work.

Therefore, as a continuation of this study, the team intends to deepen the research through selected case studies in Brazil and China, with the aim of updating the data and developing a bespoke evaluation methodology focused on the group's objectives. Our goal is to improve the quality of urban planning, development, and project design, rather than standardising the BRT brand.

THE BUS RAPID TRANSIT (BRT) SYSTEMS

The Bus Rapid Transit (BRT) systems have played a crucial role in transforming urban transportation worldwide, offering an efficient and sustainable alternative to private vehicle use, bringing economic benefits and positive environmental impacts. BRT is an innovation in urban transport systems, with its characterization, standardisation, and quality assessment conducted by the Institute for Transportation and Development Policy (ITDP)[5]. The ITDP initiative created a unified standard, ensuring that only high-quality projects are recognized and promoted. First released in 2012, the BRT Standard was developed to help cities understand and implement high-quality bus rapid transit (BRT) systems. Inspired by Bogotá's TransMilenio and Curitiba's system, the Standard aimed to define and clarify the essential elements of BRT, which was a relatively new and not well-understood innovation at the time. With the implementation of the BRT Quality Standard, corridors are evaluated and certified as gold, silver, bronze, or basic, reflecting international best practices and raising the standard of public transportation globally. The ITDP aims to protect the BRT brand and globally recognize systems that exemplify excellence in rapid bus transit.

According to ITDP[6] the BRT Quality Standard should be applied to specific BRT corridors rather than the entire BRT system, as the quality can vary significantly in cities with multiple corridors in operation. For the purposes of applying the BRT Quality Standard, a BRT corridor is defined as: A section of a road or contiguous roads served by one or multiple bus lines, with a minimum length of 3 km, featuring a segregated lane exclusively for bus traffic.

The main reason for defining the corridor this way is that in some cities, BRT does not have priority over automobile traffic, which is essential for improving both efficiency and cost. To avoid considering systems that do not make this policy choice, the corridor must include segregated lanes exclusively for buses. This definition excludes corridors that have exclusive lanes for both buses and taxis, as the presence of taxis can reduce the speed gains of the buses and the regularity of service for passengers, thereby diminishing the system's ability to attract private vehicle users.

The Basic[7] BRT is defined by five essential elements identified by the ITDP's Technical Committee to distinguish it from regular bus services. These elements are segregated infrastructure with priority passage, bus lane alignment, off-board fare collection, intersection treatment, and level boarding. Each element contributes to reducing delays from congestion and conflicts with other vehicles, enhancing efficiency, and lowering operational costs. To qualify as BRT, a corridor must have[8]: a) at least 3 km of segregated lanes exclusively for bus traffic; b) segregated infrastructure with priority passage (segregated lanes separated by a painted line on the pavement is a minimum required); c) bus lane alignment element; and d) a minimum of 20 points in total across the five Basic ITDP's standard BRT elements. It is noteworthy that the BRT Quality Standard developed by ITDP can be easily applied to rail transport corridors, particularly to trams and light rail vehicles (LRVs)[9]. In fact, we can observe the integration between BRT and LRT in Rio de Janeiro, which has been implemented in recent years with complete integration between the two systems at the Gentileza Terminal[10].

The BRT rating system[11], which awards up to 100 points, is broken down into several categories, each focused on essential aspects for the efficient and safe operation of the service. These categories include Basic BRT, Service Planning, Stations and Buses, Communications, Access and Integration, and Operations.

Fig.3. The Belo Horizonte BRT.

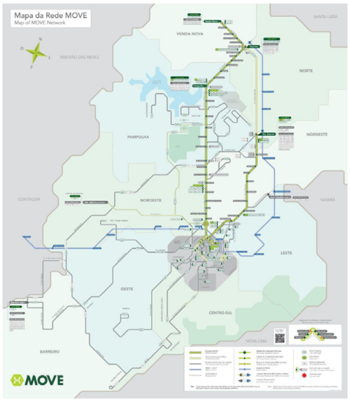

Fig. 4. Map of Belo Horizonte's MOVE network, the green lines represent BRT corridors.

The Basic BRT category has a maximum score of 35 points, distributed across five main criteria: segregated infrastructure with priority passing (7 points), alignment of bus lanes (7 points), fare collection outside the bus (7 points), treatment of intersections (7 points), and level boarding (7 points). Service Planning, with a maximum score of 18 points, evaluates multiple lines (4 points), express, limited, and local services (3 points), control centres (3 points), location among the top ten corridors (3 points), demand profile (2 points), and hours of operation (3 points).

Stations and Buses, another category, has a maximum score of 23 points and assesses aspects such as overtaking lanes at stations (3 points), minimising bus emissions (3 points), stations away from intersections (2 points), central stations (2 points), pavement quality (2 points), distance between stations (2 points), safe and comfortable stations (3 points), the number of bus doors (1 point), shoulder bays and sub-stops (2 points), sliding doors at BRT stations (2 points), and cycle infrastructure (1 point).

Communications, with a maximum score of 8 points, evaluates brand consolidation and passenger information. The Access and Integration category, with a maximum score of 16 points, includes universal access (3 points), integration with other modes of public transport (2 points), road safety and pedestrian access (4 points), secure bicycle parking (1 point), integration with bike-sharing systems (2 points), and cycle infrastructure (1 point).

The Operations category includes deductions that can total up to -77 points, applied for problems such as inadequate commercial speeds (-10 points), peak hour passengers per direction of less than 1,000 (-10 points), lack of enforcement of passing priority (-7 points), a significant gap between bus and platform (-7 points), overcrowding (-7 points), poorly maintained infrastructure (-14 points), low peak frequency (-6 points), low off-peak frequency (-4 points), unsafe use of bicycles (-3 points), lack of road safety data (-3 points), bus lanes running parallel to the BRT corridor (-3 points), and bus convoy formation (-2 points).

IMPORTANCE OF BRAZIL AND CHINA IN THE BRT LANDSCAPE

The BRT system has become an important form of public transport in South America and Asia, where there has been heavy investment in creating corridors and increasing the number of stations. Data provided by the Global BRTData website[12], developed by the company BRT+ CoE[13], indicates that the country with the highest number of users in the world is Brazil, with an average of 8,824,386 users per day in 2024, while second place is occupied by China, with 4,375,250 users. The high number of passengers in the large cities of Brazil and China, such as Rio de Janeiro, São Paulo, Guangzhou and Zhengzhou, indicate that BRT represents an important means of transport within the urban space of these countries. Figure 1 shows the landscape of BRT in Brazil and China in terms of number of passengers per day and Km of BRT corridors.

The gold standard, according to the official BRT Quality Standard document, represents those systems that "have the greatest potential to inspire the public and encourage other cities to adopt them", with the highest level of performance and operational efficiency. In Brazil, the corridors that receive this classification are Move - Cristiano Machado in Belo Horizonte, Linha Verde in Curitiba and Transcarioca in Rio de Janeiro. In China, the city of Yichang, on the Yixing Ave-Dongshan Ave-Jucheng Rd corridor, have been awarded the gold standard.

MOVE (Figure 3 and 4) is a system of BRT corridors serving high-demand areas in Belo Horizonte, Brazil. One of the system's most notable corridors is MOVE Cristiano Machado, classified as Gold, with a length of 7.1 kilometres and serving approximately 185,000 users a day.

The Cristiano Machado MOVE stands out for its ability to enter the city centre, a region where demand for public transport is extremely high and available space is limited. This corridor has been essential for improving urban mobility in one of Belo Horizonte's most congested areas, providing fast and efficient transport for thousands of passengers every day.

However, there are some points for improvement that could further optimise the efficiency of this corridor. One of the challenges is the waiting time at intersections, which could be reduced by implementing more restrictions on vehicle conversions. In addition, creating pedestrian crossings in the middle of blocks would make it easier for users to access stations outside the city centre, improving safety and convenience for pedestrians.

The Yichang BRT (Figure 6 and 7), located in Yichang, China, is a transport corridor classified as Gold, with a length of 23 kilometres and serving approximately 240,000 users daily. This BRT system is renowned for its efficiency and ability to serve a large number of passengers quickly and effectively.

One of the main strengths of the Yichang BRT is the use of overtaking lanes in its direct line system. This allows a wide range of different bus routes to use the same BRT corridor, optimising the flow of vehicles and ensuring that passengers can reach their destinations with less waiting time and greater reliability.

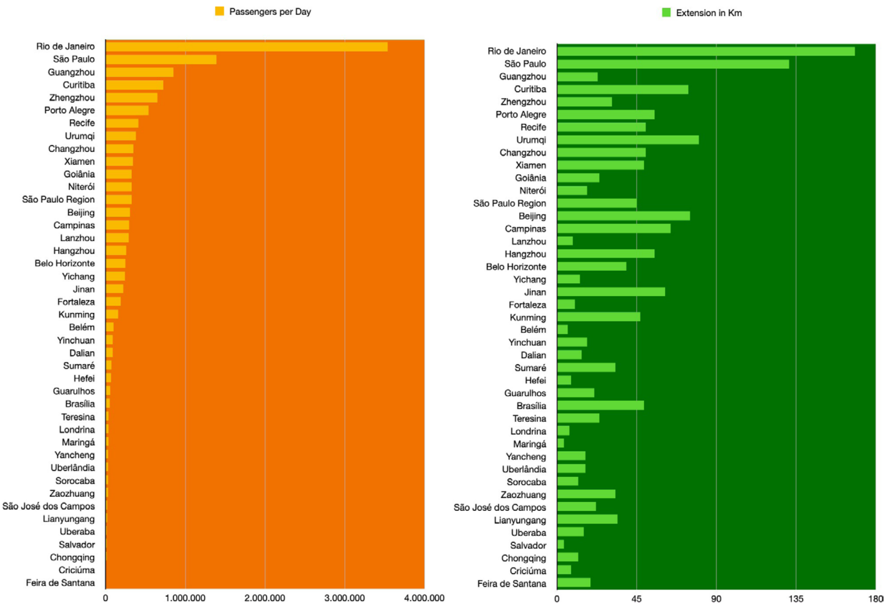

Fig. 5. BRT Landscape in Brazil and China. The cities in both countries are listed in order of the number of passengers per day. The green chart indicates the length of BRT corridors in kilometres.

Despite its success, there are areas where the system could be improved to benefit users even more. The continuity of cycle paths along the corridor is one of them. Improving the cycle infrastructure and providing more cycle parking would encourage the use of bicycles as a complementary means of transport. In addition, the implementation of a bike-sharing system could make it easier for passengers to access BRT stations, making the system even more integrated and accessible.

THE BRT SYSTEM INNOVATION BENCHMARK

To develop a future collaborative study, we draw from Curitiba's experience and highlight four innovative strategies to create analysis criteria for evaluating recent BRT experiences in Brazil and China. These strategies include: 1. holistic urban planning, 2. collaboration between various sectors, 3. focus on user experience, and 4. integration with urban space.

The quality of station design and the construction of exclusive lanes with high-quality paving are essential. Stations must be designed to offer comfort and safety, with wide spaces to prevent overcrowding, attractive design, and seamless integration with the urban environment. The paving of exclusive lanes must be highly durable, with a lifespan of at least 30 years, ensuring a smooth and comfortable journey for all passengers. Additionally, the layout should avoid steep gradients and sharp curves.

Fig.5 & 6.. The Yichang BRT.

Among the primary strategies is the adoption of innovative features that improve accessibility, such as platform-level boarding. It is crucial to ensure that the vertical gap is less than 2 cm and that there are no steps inside the buses. Horizontal gaps should be eliminated or kept below 10 cm, using electronic or physical guidance systems to facilitate safe boarding, especially for wheelchair users.

Integrating stations with urban design is vital for facilitating pedestrian access. Safe and comfortable pathways must be established between stations and surrounding areas, promoting a fluid connection and encouraging the use of public transport. By focusing on these aspects, the BRT system can offer a more accessible, efficient, and attractive public transport experience for all users.

Sustainability is another key point. Reducing bus emissions, preferably by using electric or hydrogen vehicles, significantly mitigates urban pollution. Additionally, integrating corridor layouts with landscaping projects can enhance environmental quality. These projects can provide more shade and comfort on hot days, create permeable areas to absorb rainwater, and incorporate greywater collection systems for irrigating gardens and green spaces. This combination not only improves the ecological footprint of the BRT system but also enhances the overall urban environment, making it more pleasant and sustainable for residents and passengers alike.

Collaboration between various sectors is extremely important. Teams developing urban design, terminal architecture, and vehicle design need to work integratively to achieve high-quality results in urban development and the public transport system. This collaborative approach ensures that all aspects of the BRT system are optimised, offering a superior user experience.

CONCLUDING REMARKS

The innovations initiated in Curitiba have spread to other cities in Latin America, Brazil, and more recently, China. Currently, Brazil has the largest network of BRTs in the world, followed by China, which has been rapidly growing in this sector. Initially, the BRT was adopted in Brazilian cities with up to 2 million inhabitants that did not have an established metro system, such as Belo Horizonte. It became an attractive alternative for high-capacity transport, offering a more economical solution for cities without the resources to build a metro. In Belo Horizonte and Bogotá, the system plays a crucial role in transporting large numbers of people between the central region and the outskirts through express corridors. Both have been certified by the ITDP with the gold standard.

This study identifies that despite the gold certification, numerous technological innovations, and system evolution, the central focus and innovative potential that were at the origin of the BRT are not being fully explored in Belo Horizonte, for example. The innovation of Curitiba's BRT lies in its holistic approach, integrating urban planning, transportation systems, urban design, vehicle design, and the architecture of terminals and stations—areas traditionally related but never combined so cohesively in a single project. In vehicle design for the BRT, collaboration with Volvo was crucial, resulting in the creation of articulated and bi-articulated models that meet the system's specific requirements. The architecture of the terminals, integrated with service management, enabled the implementation of a single fare, speeding up passenger boarding and line transfers. However, in current systems like that of Belo Horizonte, urban design does not prioritise pedestrians. The focus is on the immediate solution of access to terminals and the design of dedicated bus lanes in the BRT corridors, neglecting the comprehensive integration that marked the initial innovations of the system.

Another point observed in this study is that in recent years, major metropolitan areas like São Paulo and Rio de Janeiro have been investing in BRTs, even though they already have a metro network. This trend is also seen in China, in cities like Wuhan and Guangzhou. Therefore, the question arises: why are large metropolises that already have a metro system investing in BRT?

Like Brazil, China has adopted and advanced these innovations, contributing to the evolution of BRT systems. Both countries have observed significant improvements in BRT stations and the integration of inclusive urban projects, transforming public spaces around terminals and elevating the architectural importance of these structures. Innovations range from urban planning along BRT corridors to the incorporation of technologies for intelligent traffic management and automated fare collection. Our study starts with the ITDP initiative but expands the scope of innovation by considering aspects beyond the BRT brand, incorporating essential elements of the human experience in urban spaces and being sensitive to other innovative solutions that can complement the BRT system.

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DISCLOSURE STATEMENT

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2. Ibid.
3. Volvo Buses, Bus Rapid Transit.
4. These institutes and information sources are: Institute for Transportation and Development Policy - ITDP (itdp.org); BRT+CeO - Centre of Excellence for BRT studies (brt.cl); MobiliDados (mobilidados.org.br); Atlas ITDP (atlas.itdp.org), e BRT Data (brtdata.org)
5. The BRT Standard is the centerpiece of a global effort by leaders in bus transportation design to establish a common definition of bus rapid transit (BRT) and ensure that BRT systems more uniformly deliver world-class passenger experiences, significant economic benefits, and positive environmental impacts. https://www.itdp.org/2016/06/21/the-brt-standard/
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