Bus Rapid Transit [BRT]'s Green Revolution: Investigating Environmental Mitigation, Social Inclusion, and Transferrable Solutions for Sustainable Mobility

By: Omar Ajaz, December 2023

Abstract

Bus Rapid Transit (BRT) has gained popularity worldwide, deployed in large spans in over 188 cities, moving over 32 million passengers on average, per day. BRTs are prominent in the global south because they offer many benefits for cities that face challenges such as congestion, pollution, poverty, and rapid urbanization. BRTs are considered a cost-effective, flexible, inclusive, sustainable means of transit when compared to other modes, however, they require careful planning, design, implementation, and management to achieve their full potential. The Institute for Transportation and Development Policy [ITDP], several research institutions and internationals journals have provided essential standards that they recommend of what constitutes an efficient BRT system. A key short coming of these standards is that they are not legally binding or universally accepted, the grading systems are useful in understanding the quality of the system being deployed but they may not capture the full range of benefits and impacts of BRT systems, such as social inclusion, land use, urban design, economic development, and environmental sustainability or reflect the local context and preferences of different cities and regions, such as culture, geography, politics, and institutional capacity.

This research provides a comprehensive qualitative analysis exploring best practices across highly regarded BRT systems in Brazil, Colombia, India, and Indonesia of how they have successfully generated significant carbon emission savings since deployment while providing improved and inclusive accessibility, mobility and safety on public transport.

The paper further constitutes of a comparative analysis of two case studies within India where the outcomes have several contrasts and aims to assess the transferability of the best practices, considering the contextual characteristics within a region.

This research underscores the significance of BRT as a sustainable transportation solution, drawing on global best practices and case studies from India. The findings emphasize the importance of adapting strategies to local contexts, engaging stakeholders, and integrating BRT into broader urban development plans. Future research directions should explore multi-country assessments, socio-economic impacts, and the integration of emerging technologies to further enhance the effectiveness and sustainability of BRT systems globally.

Finally, the paper provides recommendations that aim to guide policymakers and urban planners in creating and implementing effective BRT systems. The suggestions emphasize collaboration, adaptability, and a holistic approach to sustainable urban transportation.

Contents

1. Introduction

Bus Rapid Transit (BRT) has gained popularity worldwide and is defined as a bus-based transportation system that provides metro-level capacity services that are simple in design, efficient in service and serves as a cost-effective alternative to urban rail investment. Compared to standard bus services, BRT systems bypass the kind of delays that often cause ordinary bus services to lag, such as traffic jams and standing in line to pay on board (Institute for Transportation and Development Policy [ITDP], 2014). “These systems have emerged as efficient, convenient, and cost-effective solutions to meet customer transport needs” (Nadeem et al., 2021).

Over 188 cities worldwide have deployed BRT systems to date, moving over 32 million passengers on average, per day. Currently, there are multiple BRT dedicated corridors, spanning 5,712 km of routes, over 6,700 stations, and a surplus of over 30,000 buses in BRT networks across the world (BRTDATA.ORG, 2023).

Since BRT systems have been introduced in developing and developed nations, numerous studies have assessed the aspects of service quality such as the socio-economic and environmental outcomes and have questioned whether the introduction of these services have achieved what they were envisaged to achieve. Despite this, there are still unanswered questions surrounding what the best practices in achieving sustainable outcomes concerning environmental mitigation and social inclusion are, which this paper seeks to fulfil through the following objective and research questions.

The research objective of this paper is to:

1. Undertake a review of the literature research around BRT systems within regions of the global south.
2. Analyse several case studies to establish a code of best practices that resulted in an environmental benefit and provided social value considering the outcomes with respect to environmental impact mitigation and poverty or social exclusion.

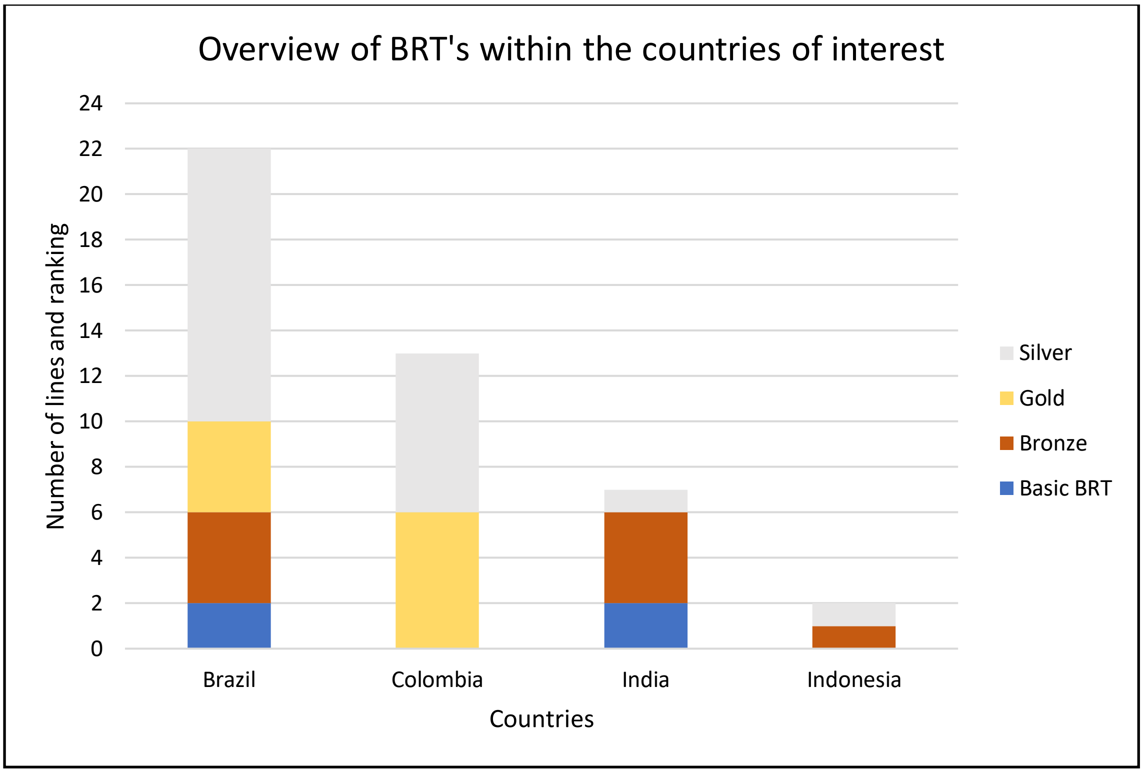
*Note: The approach in arriving at the best practices for environmental benefit and social exclusion are a broad generalisation across various regions and not focusing on a particular social or environmental aspect. Eg, focusing on air quality impact or safety for vulnerable groups.

3. Assess the transferability of best practices to constitute a successful BRT system.
4. Finally, The paper compares two case studies within the same country where the outcomes have several contrasts and aims to assess the transferability of the best practices, considering the contextual characteristics within a region.

The countries within the global south whose BRT case studies are being assessed are Brazil, Columbia, India and Indonesia. The two case studies being compared are the case studies of the BRT systems of Ahmedabad and Delhi within India.

The countries being examined in this paper have all implemented BRT systems to varying degrees of success, each tailored to the unique needs and challenges of their urban environments. BRT systems in these countries have contributed to reduced congestion, improved air quality, enhanced accessibility, and increased efficiency in public transportation (UN Climate Change, 2023) (WRI India, 2016) (ITDP , 2019) (Centre For Public Impact, 2016).

Figure 1: BRT rankings from the ITDP for each of the mentioned countries (ITDP, 2023).



India whose case studies are being thoroughly compared in later sections has seen the most polarising implementation of BRT systems. Yet to have a gold ranking system with the ITDP, several studies have concluded that BRTs in India have largely been failures. In fact, Harsha (2022) has attributed the failure to not a single BRT in India achieving the projected ridership. *"The primary reason for less ridership is strong opposition from the public"*, and the Delhi BRT was discontinued for the same reason (Harsha, 2022). Whereas the World Resources Institute [WRI] India has quoted it cities such as Ahmedabad, Indore and Bhopal's BRT systems as *"An Inspiration for Other Countries"*, with several visiting countries wanting to replicate such success and address various urban mobility challenges in their own BRT systems (Basheer, Boelens and Bijl, 2020) (WRI India, 2016). Pune, another notable city and BRT system within India are having talks to dismantle portions of its BRT system due to the congestion issues the services have been blamed to cause (Dolare, 2023). However, it is argued that by some media outlets as well as the ITDP that "Scrapping BRTs in Pune will increase congestion and travel time" (Bengrut and Hindustan Times News, 2022).

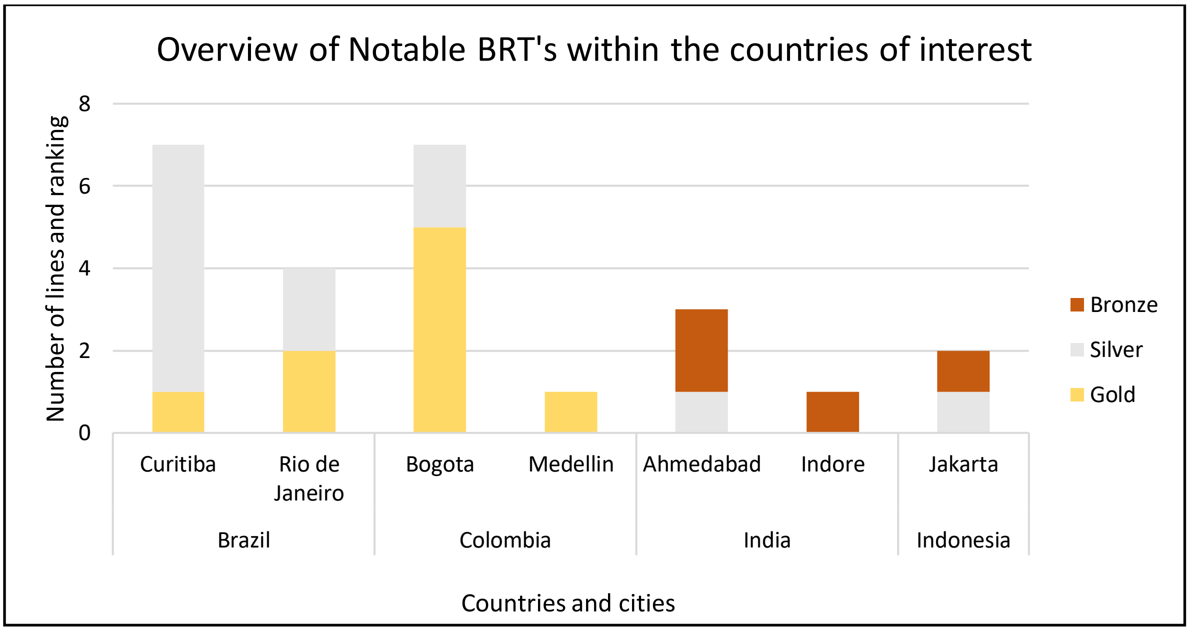
This disparity in outcomes between the implementation of BRT systems in India cities, i.e., the success being reaped in the Ahmedabad BRT system (Rana, 2022) and the discontinuation of the Delhi BRT system is examined understand why this has happened and to arrive at the best practices in policies and implementation with an aim to guide policymakers and urban planners in implementing effective BRT systems.

2. Literature Review

2.1 BRT Systems overview in the Global South

An overview of the BRT systems in the four countries are as follows, the data has been collated from the ITDP's BRT rankings and only the case studies being examined have been included.

Figure 2: Specific BRTs of interest rankings from the ITDP for each of the mentioned countries (ITDP, 2023).



Brazil was one of the early adopters of BRT systems and has a well-established network. BRT systems in Brazil are known for their efficiency and impact on urban mobility (Kerkhof, 2014). The Notable BRT Systems are within the following cities:

- Curitiba: The city of Curitiba is often credited with pioneering the concept of BRT in the 1970s with its 'Rede Integrada de Transporte' (Integrated Transport Network). It serves as a global model for BRT systems (Milwaukee, 2022).
- Rio de Janeiro: Rio de Janeiro has implemented the TransMilenio system, connecting different parts of the city and enhancing public transportation (Lemoine et al., 2016).

Both BRT systems have received gold recognition by the ITDP as shown (in figure 2) and have been quoted by some studies as "*among the best in the world*" (Louzas, 2013).

Colombia is renowned for its extensive and successful BRT systems, particularly in Bogotá. These systems have transformed urban transportation in the country. The Notable BRT Systems are within, the following cities:

- Bogotá: TransMilenio is Bogotá's flagship BRT system and one of the world's largest BRT networks. It has significantly improved urban mobility and reduced congestion (Turner et. al, 2012).
- Medellín: The Metroplús BRT system in Medellín is known for its integration with other modes of transportation, such as the metro and cable cars.

Both city's BRT systems have received gold recognition by the ITDP, in particular, Bogotá has been quoted as "*a world-renowned BRT system*"(Hudson and Greater Washington, 2017) seeing success on various fronts in terms of improving urban mobility and serving urban growth (Basheer, Boelens and Bijl, 2020).

Indonesia has adopted BRT systems to alleviate traffic congestion in its urban centers. BRT has contributed to improving public transportation options in the country (Ernst and Sutomo, 2010). The Notable BRT Systems are within, the following cities:

- Jakarta: Jakarta's TransJakarta BRT system is one of the most extensive BRT networks in the world. It has been instrumental in addressing traffic congestion and enhancing urban mobility (ITDP, 2019).

The ITDP has commended the Jakarta BRT as “A study in success” for flawless implementation and continuous expansion over the last 2 decades. Aside from the system, Jakarta has also received an Honourable Mention in the 2020 Sustainable Transport Awards, much of this is also attributed to the BRT system and governance of promoting sustainable transport within the city (ITDP, 2019).

India has also embraced BRT systems as a solution to address urban mobility challenges in its rapidly growing cities. BRT has gained prominence as an efficient public transportation mode. The Notable BRT Systems are within, the following cities:

- Ahmedabad: The Janmarg BRT system in Ahmedabad was one of the early successes in India and has expanded its network over the years (Basheer, Boelens and Bijl, 2020).
- Indore: iBus project was initiated to improve public transportation, reduce congestion, and enhance urban mobility in the city.

All in all, the above cities BRT case studies constitute how BRT can address urban mobility challenges in diverse geographic and socio-economic contexts. These case studies are further examined in later sections and their implementation of the best practices, and their socio-environmental outcomes have been discussed.

2.2 Case Studies

Curitiba, Brazil:

- Implemented the first BRT system in the world in 1974.
- Segregated bus lanes, tube-shaped stations, pre-ticketing, and flat fare
- Integrated with urban planning and land use policies.
- Reduced travel time, congestion, pollution, and greenhouse gas emissions.
- Improved road safety, accessibility, mobility, and social inclusion
- Saved 27 million hours of travel time and 27,000 tons of CO2 emissions per year.

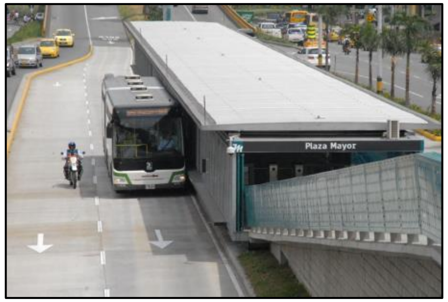
Bogotá, Colombia:

- Several interconnected bus lanes, tube-shaped stations, pre-ticketing, and flat fare
- Integrated with urban planning and land use policies
- Served about 2.4 million passengers daily, more than many metro systems
- Reduced travel time, congestion, pollution, and greenhouse gas emissions
- Improved road safety, accessibility, mobility, and quality of life
- Saved 27 million hours of travel time and 27,000 tons of CO2 emissions per year

Rio de Janeiro, Brazil:

- Launched the first BRT system in 2012, expanded to three lines.
- Dedicated bus lanes, modern stations, smart ticketing, and integration with other modes of transport
- Improved the travel conditions and options for millions of people, especially in low-income and peripheral neighbourhoods.
- Reduced travel time by 50%, saved 75,000 tons of CO2 emissions per year, and created 13,000 jobs

Medellín, Colombia:



- Started a BRT system called Metroplús in 2011
- Part of the Integrated Transport System of the Aburrá Valley, which also includes a metro, a tram, and cable cars.
- Two bus priority corridors that cover 18 kilometres and benefit 60,000 passengers every day.
- Modern stations, smart ticketing, and integration with other modes of transport
- Improved the travel conditions and options for millions of people, especially in low-income and peripheral neighbourhoods.
- Reduced travel time by 50%, saved 75,000 tons of CO2 emissions per year, and created 13,000 jobs

Ahmedabad, India:

- Dedicated bus lanes, modern stations, smart ticketing, and integration with other modes of transport
- Covers 160 km, with 89 km of dedicated bus lanes, 162 stations, and 380 buses, including 150 electric buses.
- Caters to around 200,000 to 220,000 passengers daily.
- Improves the travel conditions and options for millions of people, especially in low-income and peripheral neighbourhoods.
- Reduces travel time, congestion, pollution, and greenhouse gas emissions.
- Improves road safety, accessibility, mobility, and quality of life.

Indore, India:

- iBus, operated by Atal Indore City Transport Services Ltd, became operational in May 2013
- Bus-only lanes, median stations, and custom-designed buses
- Free high-speed Wi-Fi internet service for commuters
- Intelligent Transport System, with advance signal systems, GPS-enabled buses, a public information system, and a centralised control centre
- Automatic Fare Collection System, with contactless smart cards
- Consists of 11.5 km of bus-only lanes, 21 median stations, and expected to serve 70,000 passengers per day.

Jakarta, Indonesia:

- TransJakarta, the first BRT system in Southeast Asia, started in 2004.
- Segregated bus lanes, tube-shaped stations, pre-ticketing, and flat fare
- Integrated with urban planning and land use policies.
- The world's longest BRT system, with 251.2 km of dedicated bus lanes, 244 stations, and about 4,300 buses
- Serves an average of 1.006 million passengers daily.
- Reduces travel time, congestion, pollution, and greenhouse gas emissions.
- Improves road safety, accessibility, mobility, and quality of life.

2.3 Global BRT best practices

The "BRT Standard '', produced by the ITDP, is the global standard grading system used to uniformly evaluate BRT systems that considers its economic, passenger and environmental benefit impacts (ITDP, 2016). The ITDP has classified the BRT systems within these countries to assess and evaluate the performance of transportation systems. These scorecards are a set of criteria and indicators used to measure how well a City's BRT network aligns with certain goals, standards, and best practices. The scores are often presented in a format that makes it easy for stakeholders and the public to understand how a system performs in various categories. The specific criteria and indicators used in these scorecards can vary, but they generally include elements such as: Infrastructure Quality; Service Quality; Integration; Sustainability; Accessibility; Safety and Security; and Economic Viability (ITDP, 2023).

A key short coming of this standard is that they are not legally binding or universally accepted, so some cities may claim to have BRT systems that do not meet the standards or may not seek certification at all (ITDP, 2014b). While the grading systems are useful in understanding the quality of the system being deployed, they may not capture the full range of benefits and impacts of BRT systems, such as social inclusion, land use, urban design, economic development, and environmental sustainability or reflect the local context and preferences of different cities and regions, such as culture, geography, politics, and institutional capacity (ITDP, 2014).

Table 1: BRT standard grading system explained (ITDP, 2016).

Rating	*Explanation*
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 level of operational performance and efficiency 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, as well as 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.

Similarly, the C40 Cities Climate Leadership Group has developed a series of Good Practice Guides, and one of these practice guides highlight the essential components required to build an efficient and successful BRT system, which will improve cities' social, economic, and environmental results (C40 Cities Climate Leadership Group ,2016).

The following global best practices and their outcomes on their impact on environmental mitigation and social inclusion have been synthesised from the above documents and with reference to various research papers.

Table 2: BRT best practices from various studies and guidelines and their Socio-environmental outcomes

	Best Practice	**Impact on Environmental Mitigation**	**Impact on Social Inclusion**	**References**
1	Dedicated Bus Lanes	Dedicated lanes contribute to reduced traffic congestion, leading to lower emissions and improved air quality.	Dedicated lanes enhance the reliability of bus services, making public transportation more attractive and accessible to a broader range of passengers.	(Shbeeb, 2023), (Mead, 2021), (He, Yang and Li, 2021), (C40 Knowledge Hub, 2023)
2	Inclusive Design and Accessibility, such as ramps, elevators, and priority seating ensure accessibility for people with disabilities and diverse mobility needs	By promoting inclusivity, BRT systems encourage a shift from private vehicles to public transport, reducing overall emissions.	Inclusive design fosters an environment where public transportation is accessible to all, promoting social equity.	(C40 Knowledge Hub, 2023), (C40 Knowledge, 2019), (Dasgupta and Puliti, 2022), (CABE, 2008)
3	Integration with other modes of transport, such as metro systems and cycling networks, creates a comprehensive urban transportation network.	Encourages seamless transitions between modes, reducing the need for private vehicle usage and decreasing emissions.	Provides passengers with a range of transportation options, catering to different preferences and needs.	(C40 Knowledge, 2019), (C40 Knowledge Hub, 2023),
4	Implementation of affordable fare structures and integration with other transportation modes.	Affordable fares make public transport an attractive option, reducing reliance on private vehicles and associated emissions.	Ensures that public transportation is economically accessible to diverse socio-economic groups, promoting inclusivity.	(C40 knowledge, 2021)
5	Integration of technology for real-time information displays, smart ticketing, and other passenger-friendly features.	Integration of technology for real-time information displays, smart ticketing, and other passenger-friendly features.	Enhances the overall passenger experience, making public transportation more user-friendly and accessible to a wider audience.	(C40 knowledge, 2021), (Barr et al., 2010)
6	Involvement of the community in the	Fosters a sense of ownership and support	Ensures that the needs and concerns of	(C40 Knowledge Hub, 2023)

	planning and implementation of BRT systems.	for sustainable transportation initiatives, encouraging a shift away from individual car usage.	the community are considered, leading to transportation solutions that cater to a diverse population.	
7	Implementation of safety measures, including women-only buses during peak hours.	Enhances the safety and security of public transport, encouraging more people to use BRT instead of private vehicles.	Addresses safety concerns, making public transport a safer option, particularly for women, thereby promoting social inclusion.	(C40 knowledge, 2021), (Navarrete-Hernandez and Christopher Zegras, 2023)
8	Seeking environmental certifications and incorporating sustainable practices in the design and operation of BRT systems	Demonstrates a commitment to sustainability, encouraging environmentally conscious travel choices.	Reflects a broader commitment to creating inclusive, sustainable urban environments, positively impacting the quality of life for all residents.	(Krüger et al., 2021), (ITDP, 2018)

3. Methodology

The methodology consists of three main steps: data collection, case study selection, and analysis.

3.1 Data Collection

The data collection process involved two main sources of information:

- Literature Review: A comprehensive review of academic papers, international standards, reports, and articles related to BRT systems, sustainable transportation, and urban planning. The literature review provided the theoretical background and the conceptual framework for the study, as well as the identification of the main criteria and indicators for evaluating BRT systems.
- Case Studies: In-depth examination of BRT systems globally, with a focus on cities with the highest success levels of implementation. This involved collecting data on infrastructure, ridership, environmental impact, and social inclusion aspects. The case studies provided the empirical evidence and the best practices for BRT systems.

3.2 Case Study Selection

The case study selection was the following :

- Global Best Practices: Selection of global case studies based on the reputation of the BRT system, its impact on environmental mitigation, and its success in promoting social inclusion. The selected case studies were Curitiba (Brazil), Rio de Janeiro (Brazil), Bogotá (Colombia), Medellín (Colombia), and Jakarta (Indonesia), Ahmedabad (India), Indore (India).
- Indian Context: India was selected due to the polarising implementation and scrapping talks of BRTs within other cities. Considering the diversity of cities and the success of BRT systems in Ahmedabad and Indore. The selected case studies were Ahmedabad and New Delhi.

3.3 Analysis

The analysis process involved two main methods:

- Qualitative Analysis: A qualitative method that allows the interpretation and understanding of the context and the nuances of BRT implementation. The qualitative analysis was based on the data gathered from case studies and literature review, and focused on the success factors, challenges, and lessons learned from BRT systems.

- Multi-Criteria Analysis (MCA): A quantitative method that allows the comparison and ranking of different alternatives based on multiple criteria and indicators. The MCA was used to evaluate the performance of BRT systems in terms of environmental impact and social inclusion. The criteria and indicators used were:
  1. Environmental Impact: Reduction in traffic congestion, decrease in emissions, and improvements in air quality. This criterion assessed the environmental sustainability of BRT systems and their contribution to mitigating climate change.
  2. Social Inclusion: Inclusive design features, affordability, safety measures, and community engagement. This criterion evaluated the extent to which BRT systems considered the needs of diverse populations, ensuring accessibility and social equity.

The results of the analysis were used to answer the research questions and to provide recommendations for improving BRT systems globally.

4. Results& Discussion

4.1 Environmental Mitigation through BRT systems

This section discusses how BRT systems have been observed to positively influence the environment of the cities they have been deployed in, with references to the case studies being examined.

BRT systems are designed to provide efficient and rapid transit, leading to reduced congestion on roadways. Designing and enforcing dedicated bus lane optimise traffic flow, enhancing the overall efficiency and environmental performance of BRT systems (Nikita's and Karlsson, 2015). BRT systems that implement cleaner technologies and green fleet management practices, contribute to a reduction in greenhouse gas emissions, particularly in terms of carbon dioxide (CO_2) and other pollutants, positively impacts air quality within the city.

Notable implementation in cities such as Bogotá, Rio de Janeiro and Jakarta, where dedicated bus lanes have been enforced within their network designs, have optimised traffic flow and reduced overall emissions. Electric buses are being adopted by transit agencies and local governments all throughout Latin America in an effort to save fuel costs, enhance air quality, and counteract rising greenhouse gas emission (GreenBiz and Gallucci, 2019).

Bogotá has been reaping the environmental benefits in the form of reduced GHG and other air pollutant emissions. The annual average estimated reduction of CO_2 emissions amounts to 578,918 tCO_2eq which is equivalent to the emissions of around 123,174 cars per year (Mann, 2018). Furthermore, a reduced number of vehicles in the city has led to less noise pollution (Urban Sustainability Exchange, 2023). Medellín has invested heavily in electric bus technology, showcasing a commitment to clean technologies. Every year, the system saves 175,000 tons of carbon dioxide, which is the same as planting 380,000 trees, or 11% of the total land area of the city. According to Metro, it saves the city $4 billion annually in less traffic accidents and congestion, as well as $1.5 billion in respiratory health expenses (UN habitat, 2021).

Encouraging sustainable urban planning by promoting compact, mixed-use development around transit nodes contribute to reduced sprawl, lowering the overall environmental impact of urban expansion(C40 Cities Climate Leadership Group, 2019). One of the key best practices to this extent has been integrating BRT systems with sustainable land use practices such as non-motorized modes like cycling and walking. Curitiba's BRT system integrates with sustainable land use planning, fostering "Transit-Oriented Development" around a reduced urban sprawl (Cavalcanti et al., 2017). Similarly, Medellín and Jakarta's systems integrate seamlessly with non-motorized modes, promoting cycling and walking as environmentally friendly transportation (ITDP, 2021).

Coordinated urban planning that encourages higher-density development around BRT corridors reduces the need for long commutes and supports sustainable living (Cervero and Dai, 2014). To this extent, designing BRT stations for energy efficiency and environmental sustainability by incorporating energy-efficient lighting, green spaces, and renewable energy sources in station design enhances the overall sustainability of BRT infrastructure. BRT stations in Curitiba, Jakarta and Ahmedabad incorporate energy-efficient lighting and green spaces, aligning with environmental sustainability (GCT, 2010) (Rogat et al., 2015) (United Nations, 2021).

By examining these case studies, it is evident that BRT systems globally are adopting best practices that contribute to environmental sustainability, reducing the ecological footprint of urban transportation. Therefore, the following best practices to promote environmental sustainability through BRT systems have been synthesized from the case studies:

1. Green Fleet Management: Implementing and maintaining low-emission buses, hybrid technologies, or transitioning to electric buses contributes to reducing the environmental footprint of BRT systems.
2. Dedicated Bus Lanes: Designing and enforcing dedicated bus lanes to optimize traffic flow.
3. Integration with Non-Motorized Modes: Integrating BRT systems with non-motorized modes.
4. Sustainable Land Use Planning: Coordinated urban planning that encourages higher-density development around BRT corridors reduces the need for long commutes and supports sustainable living.
5. Efficient Station Design: Designing BRT stations for energy efficiency and environmental sustainability such as energy-efficient lighting, green spaces, and renewable energy sources in station design.
6. Investment in Clean Technologies: Investing in clean and renewable technologies for BRT operations.

By incorporating these best practices, BRT systems can maximize their positive environmental impact, contributing to sustainable urban development and addressing challenges related to climate change and air quality.

4.2 Social Inclusion through BRT systems

BRT systems worldwide have demonstrated significant contributions to social inclusion by enhancing accessibility, promoting equity, and addressing the transportation needs of diverse population groups (World Resources Institute [WRI], 2013).

BRT systems often incorporate features like low-floor buses, level boarding platforms, and priority seating, making public transportation more accessible for people with disabilities, seniors, and those with mobility challenges(Rickert , 2011). Designing stations and vehicles with universal accessibility principles ensures that everyone, regardless of physical abilities, can comfortably use the system (ITDP, 2014b). Bogotá has dedicated lanes and stations designed for universal accessibility, ensuring that people with disabilities and different mobility needs can use the system seamlessly, Similarly, Medellín's BRT system's is designed with inclusive features, including ramps, elevators, and priority seating, making it accessible for all residents, including those with disabilities (World Bank, 2014).

Affordable fares make public transport accessible to a broader socio-economic spectrum, reducing economic barriers to mobility (Gates et al., 2019). By improving connectivity, BRT systems also facilitate access to job opportunities, particularly for residents in economically disadvantaged areas. Curitiba's BRT, often considered the pioneer, incorporates a fare system that is affordable for a wide range of socio-economic groups, reducing economic barriers to accessing public transportation. Bogotá has gone as far to implement fare subsidies for low-income users, making public transportation more affordable and ensuring that economic constraints do not hinder access (Development Asia, 2016) (Gómez-Lobo, 2020).

Inter-modal connectivity enhances the overall accessibility of the transportation network, allowing users to reach their destinations more efficiently (Utilities One, 2023). BRT system support this by integrating their network with other modes of transportation, such as metro, trains, and cycling. E.g., Rio de Janeiro BRT system provides passengers with a comprehensive and interconnected network that enhances accessibility and integrates with other modes of transport, such as metro and suburban trains (Kerkhof, 2014).

Engaging local communities ensures that the system meets the specific needs of diverse user groups (CABE, 2008) (Carrigan et al., 2014). Successful BRT projects involve community stakeholders in the planning and decision-making processes. Curitiba and Ahmedabad conducted extensive community consultations during the planning phase, ensuring that the BRT systems align with the specific needs and preferences of the local population (Carrigan et al., 2014). BRT systems implement public awareness campaigns to educate residents about the benefits of public transportation, encouraging social inclusivity by promoting collective benefits. E.g. Indore's system focused on universal design principles, ensuring physical accessibility for all passengers, including those with disabilities. While public awareness campaigns in Indore educate residents on the environmental benefits of using public transport (Singhai, Thakre and Tare, 2022).

BRT systems often implement security measures such as well-lit stations, surveillance cameras, and visible security personnel. This contributes to a safer and more secure environment, making public transport more appealing to a broader range of users, including vulnerable populations (Cervero, 2013). In fact, Jakarta has introduced women-only buses during peak hours, addressing safety concerns and enhancing the inclusivity of the system for women passengers (Vaswani, 2010).

In summary, BRT systems globally contribute to social inclusion through a combination of accessible infrastructure, affordability, community engagement, and safety measures.

Therefore, the following best practices have been synthesized in the above case studies to offer valuable lessons for creating BRT systems that prioritize social equity and inclusivity:

1. Equitable Route Planning: Ensuring that BRT routes reach economically disadvantaged or geographically isolated areas promotes social equity by providing essential transportation services to those who need them the most.

2. Fare Integration and Subsidies: Implementing fare integration across different modes of transportation and offering subsidies for low-income populations ensures that public transport remains financially accessible to all.

3. Inclusive Infrastructure Design: Incorporating universal design principles in station architecture and bus interiors ensures that BRT infrastructure is accessible to people with varying physical abilities.

4. Public Awareness Campaigns: BRT systems conduct campaigns to educate the public, particularly marginalized communities, about the benefits of public transportation, how to use the system, and the positive impact on their daily lives.

5. Community Engagement: Consulting with local communities during the planning and implementation phases ensures that the unique needs of different demographic groups are considered, fostering a sense of ownership and inclusivity.

By adopting these best practices, BRT systems can maximize their impact on social inclusion, ensuring that public transportation becomes a tool for promoting equity, accessibility, and community well-being.

4.3 Transferability of best practices

The transferability of best practices from BRT systems in different regions depends on various geographic, cultural, and economic factors that affect the feasibility, suitability, and acceptability of BRT as a mode of urban transport (Nikitas and Karlsson, 2015). Replicating BRT success requires a nuanced approach that considers the unique context of each city. Learning from global best practices, adapting strategies to local conditions, and addressing specific challenges are crucial for achieving success in diverse geographic, cultural, and economic settings(Jennings, 2020).

Geographic factors, such as topography and available road space, influence BRT corridor design (Ojeda et al., 2023). Cities with flat terrain and wide roads may find it easier to replicate dedicated bus lanes, whereas cities with complex topography might face challenges in finding suitable routes for dedicated lanes. The replication may require creative engineering solutions to adapt to diverse geographic conditions. For example, BRT systems in Bogotá, Rio de Janeiro, Curitiba, and Medellín have benefited from the linear and compact urban form of these cities, which allows for high-density corridors and efficient trunk-feeder networks (ITDP, 2018a).

Clear policies and effective governance structures support BRT success. Enforcing dedicated standards, streamlining approvals, and aligning policies with urban development goals contribute to replicability. Bureaucratic hurdles, lack of political will, and inconsistent policy support can hinder successful replication. The political landscape and governance structures thus need careful consideration when proposing transit schemes (UNDESA and UNFCCC, 2023) (Global Commission on the Economy and Climate, 2016).

Adapting BRT features to align with cultural expectations and local travel behaviour is vital for success. The participation and engagement of stakeholders, the governance and regulation of BRT systems, and the social impacts of BRT affect the perception and acceptance of BRT as a mode of transport(Lindau et. al, 2014). For example, BRT systems in Bogotá, Rio de Janeiro, Curitiba, and Medellín have enjoyed strong political and public support, as well as a culture of innovation and social inclusion, which have enabled the implementation and improvement of BRT systems over time(Nicolás and Jaramillo, 2017). However, BRT systems in Ahmedabad, Indore, and Jakarta have faced resistance and opposition from some groups, such as informal transport operators, car users, and residents affected by land acquisition, which have hindered the development and expansion of BRT systems (Levinson et al., 2003). Inclusive planning that considers the needs of all social groups thus enhances BRT success. Ensuring accessibility for people with disabilities, the elderly, and other vulnerable populations contribute to social equity. Affordability, safety concerns, and perceptions of social exclusion need to be addressed for widespread acceptance (GSDRC, 2015). Technology can play a crucial role in this, from real-time information for passengers to smart ticketing systems. Adopting and customizing technology to local needs enhances user experience (Macedo et al., 2021).

Economic factors influence both BRT implementation and user adoption. Affordability, cost-effectiveness, and economic benefits contribute to success (Lindau et. al, 2014). The availability of funds and the economic viability of BRT projects are critical. Balancing the initial investment with long-term benefits can be challenging, particularly in economically constrained environments. Technological infrastructure requirements and maintenance costs can be barriers. The digital divide may also impact the accessibility of technology-driven features (Carrigan et al., 2014).

4.4 Comparative Analysis of Indian BRTs

Comparing the BRT systems in Ahmedabad and Delhi, India provides insights into the factors that contributed to the success of one system and the challenges faced by the other.

As mentioned, the transferability of best practices from BRT systems in different regions depends on various geographic, cultural, and economic factors that affect the feasibility, suitability, and acceptability. Therefore, before diving into the challenges that caused Delhi's system to fail, it is worth exploring these differences between the two cities.

Ahmedabad is located in the western state of Gujarat in India. With a population of more than 7 million people. It is a major industrial, commercial, and cultural centre, as well as a hub for education, research, and innovation (Rough Guides, 2023). Ahmedabad has a linear and compact urban form, with a high-density corridor topography (Parekh and Makwana, 2020). It has a relatively flat topography, which is conducive to the development of efficient transportation systems like the Bus Rapid Transit (BRT) system (Nikitas and Karlsson, 2015).

Delhi, the capital of India, is a vast metropolitan area with diverse topography. It encompasses both urbanized and hilly regions, which can pose geographical challenges for transportation infrastructure (Papa et al., 2022). Delhi is the capital and second-largest city of India, with a population of more than 18 million people (Ram, 2019). It is a political, administrative, and cultural centre, with a diverse and dynamic economy. Delhi has a sprawling and heterogeneous urban form, with a low-density and polycentric structure (Ram, 2019). The city faces challenges such as severe traffic congestion, air pollution, road accidents, and inadequate public transport (Verma et al., 2021).

The geographic features of each city played a significant role in the success or challenges faced by their respective BRT systems.

Ahmedabad's BRT system takes advantage of the city's flat terrain and the availability of dedicated road space to create efficient bus corridors. The city's geographical layout allowed for the relatively straightforward construction of dedicated bus lanes (Gohel, 2014). In contrast, Delhi's geographical complexity, with hilly areas and dense urbanization, presented a challenging environment for BRT implementation (Rizvi, 2014). Part of Delhi's BRT system faced issues related to the design and allocation of road space in a densely populated and hilly region.

Ahmedabad's BRT system was launched in 2009 as a part of the city's comprehensive mobility plan. The BRT covers 160 km of network, with 89 km of dedicated corridors and 162 stations. It uses modern and accessible buses, smart card-based fare collection, and intelligent transport systems. It serves about 2.2 lakh passengers per day (Joshi and Mahadevia, 2013).

The BRT has achieved significant environmental and social outcomes, such as (Rizvi, 2014) (Jaiswal et al., 2012) (Joshi and Mahadevia, 2013) (Rizvi and Sclar, 2014):

- Reducing greenhouse gas emissions by 163,000 tonnes per year, and local air pollutants by 20 to 30 % (Pathak and Shukla, 2015).
- Improving travel speed by 30 to 40%, and travel time by 20 to 25 %.
- Enhancing accessibility and mobility for low-income and vulnerable groups, such as women, elderly, disabled, and students(World Bank Group, 2012)
- Increasing public transport ridership by 27%, and reducing private vehicle use by 15 %
- Creating employment and income opportunities for bus drivers, conductors, and station staff(Ahmedabad Mirror Bureau, 2012).

- Generating positive economic impacts, such as increased productivity, land value, and business activity(Ahmedabad Mirror Bureau, 2012).

The BRT has been widely recognized as a successful and innovative model of urban transport, and has won several national and international awards, such as the Sustainable Transport Award in 2010, the UITP Award for Innovation in 2011, and the ITDP Sustainable Transport Award in 2012 (TOI, 2013) (ITDP, 2010).

Ahmedabad's 'Janmarg BRT' is often considered a success, primarily due to its well-designed and efficiently managed infrastructure. It has dedicated lanes, modern buses, and is well-integrated with other modes of transportation, enhancing passenger convenience. The system has led to reduced congestion and improved air quality in the city (Eric Christian Bruun, 2005).

The Delhi BRT was launched in 2008 as a pilot project to improve the efficiency and quality of bus services. The network covered 14.5 km of network, with 5.8 km of dedicated corridors and 20 stations. It used low-floor and air-conditioned buses, electronic ticketing, and traffic signal priority. It served about 1.8 lakh passengers per day (CSIR, 2012).

The Delhi BRT faced several challenges and controversies, such as (ITDP, 2019a) (Rizvi, 2014) (Rizvi and Sclar, 2014):

- Causing more traffic congestion and accidents, due to the poor design and implementation of the BRT corridor, which reduced the road space and created conflicts with other vehicles. including limited space for private vehicles and a lack of bus shelters and pedestrian facilities. These design flaws led to traffic congestion and discontent among commuters. Delhi's BRT corridor was designed with dedicated bus lanes, but they were not effectively enforced due to this reason.
- Facing resistance and opposition from car users, politicians, media, and civil society, who criticized the BRT system as a waste of public money and a nuisance for the majority of commuters. This opposition hindered the system's success.
- Lacking adequate enforcement and regulation, which resulted in the violation of the BRT rules by motorists, cyclists, and pedestrians, who encroached on the BRT lanes and stations.
- Failing to integrate with other modes of transport, such as the metro, rail, and bus systems, which reduced the convenience and affordability of the transport network. Unlike Ahmedabad, Delhi's BRT system lacked integration with other modes of transportation, making it less convenient for passengers to switch between modes.
- Neglecting the needs and preferences of the bus users, who complained about the poor quality and reliability of the bus services, the lack of information and amenities, and the high fares.

The Delhi BRT was widely regarded as a failed and flawed experiment of urban transport, and was scrapped by the Delhi government in 2016, after a court order (Misra, 2016). The BRT corridor was dismantled and converted into a regular road. The BRT was also blamed for the defeat of the ruling party in the 2013 state elections. Furthering the need for political will in successful implementation of these systems (The Economic Times, 2015).

The Delhi BRT faced several key issues that contributed to its perceived failure. These issues included inadequate planning, design flaws, poor integration, and significant opposition from the public and political stakeholders. In essence, the failure of the Delhi BRT was due to a combination of technical, operational, and political challenges. The lack of proper planning and communication with stakeholders led to the BRT system's difficulties in achieving its intended goals.

In contrast, the Ahmedabad BRT demonstrated success due to a well-planned and well-implemented system with dedicated infrastructure, passenger-friendly features, and integration with other transportation modes. It showcased how a carefully designed and executed BRT system can be successful in addressing urban mobility challenges.

It's essential to note that while the Delhi BRT system faced challenges and criticism, it also provided valuable lessons for future BRT implementations in India and other regions, emphasizing the importance of proper planning, design, and stakeholder engagement in BRT projects (Singh, 2018) (Rizvi and Sclar, 2014).

The comparative analysis indicates that the success of a BRT system depends on effective planning, design, integration, and enforcement. While Ahmedabad's BRT system demonstrated that a well-implemented BRT system can significantly improve urban mobility, Delhi's experience underscores the importance of addressing design flaws, public perception, and integration to achieve success.

6. Conclusion, Broader Implications and Potential Future Research directions

6.1 Conclusion

BRT systems require a holistic and integrated approach to planning and implementation, which considers the geographic, cultural, and economic factors of each city, and adapts the BRT design and operation to the local needs and conditions. BRT systems also need to be coordinated and connected with other modes of transport, such as metro, rail, bike, or pedestrian facilities, to enhance the convenience and coverage of the transport network.

BRT systems need strong political and public support, as well as effective governance and regulation, to ensure their success and sustainability. BRT systems should be based on a clear vision and commitment from the stakeholders and involve a participatory and transparent process of consultation and engagement with the users and affected groups. BRT systems should also be enforced and regulated by the authorities and protected from the encroachment and violation by other vehicles and road users.

The comparative analysis of BRT systems in Delhi and Ahmedabad, revealed the critical importance of effective planning, stakeholder engagement, and adaptation to local conditions for success. Delhi's challenges highlighted the need for clear regulations, public awareness, and integration with existing infrastructure. Policymakers and urban planners should be urged to integrate BRT planning with broader urban development goals, prioritize stakeholder engagement, establish clear regulatory frameworks, embrace technological innovations, and conduct pilot programs for adaptive planning.

This research underscores the significance of BRT as a sustainable transportation solution. The findings emphasize the importance of adapting strategies to local contexts, engaging stakeholders, and integrating BRT into broader urban development plans.

6.2 Broader Implications

The success of BRT systems emphasizes the need for integrated urban planning that considers transportation as a key component of city development. Coordinated land use planning is essential to ensure that BRT corridors align with the broader urban development goals.

Effective policies and enforcement mechanisms are crucial for the success of BRT systems. Clear regulations on dedicated lanes, ticketing, and station facilities are essential. Policies should encourage public engagement and awareness campaigns to foster acceptance and support for BRT initiatives.

The success of BRT systems in promoting social inclusion emphasizes the need for inclusive design that considers the needs of all community members. Policymakers should prioritize accessible transportation solutions, incorporating features that cater to individuals with disabilities and diverse mobility needs.

The integration of technology, such as real-time information systems and smart ticketing, enhances the efficiency and accessibility of BRT systems. Policymakers should focus on creating adaptable systems that can evolve with changing urban dynamics, technological advancements, and socio-economic shifts.

In conclusion, the synthesis of global best practices, and comparative analysis on the Indian case studies provides valuable insights for shaping urban planning and policymaking. Sustainable transportation strategies, with a focus on BRT systems, have the potential to transform urban mobility globally, fostering inclusivity, environmental sustainability, and efficiency. The lessons learned can inform future initiatives and contribute to the development of transportation systems that meet the evolving needs of cities worldwide, not limiting the benefits to the global south or developing nations.

6.3 Potential future research directions

Future research should expand beyond individual city studies to encompass multi-country assessments, allowing for a broader understanding of the global dynamics of BRT implementation. This could also be explored in In-depth case studies of successful BRT systems in various regions can provide nuanced insights into the contextual factors influencing success.

Conducting longitudinal studies to assess the long-term impact of BRT systems on urban development, economic productivity, and environmental sustainability further adds to context of if the objectives the systems were proposed to address have been achieved. These studies should Investigate the socio-economic impacts of BRT systems, including their effects on employment, local businesses, and social equity. Several of these aspects area already being explored by various research publications.

Further research on the integration of emerging technologies, such as autonomous vehicles and smart city solutions, into BRT systems for enhanced efficiency and sustainability could also be a potential future direction of research to explore.

7. Recommendations and Policy Implications:

These following recommendations aim to guide policymakers and urban planners in creating and implementing effective BRT systems. They are the outcomes of this research paper. The suggestions emphasize collaboration, adaptability, and a holistic approach to sustainable urban transportation. When planning for BRTs in urban transit, policy makers and planner should:

- Conduct a comprehensive and participatory feasibility study of the BRT system. This should assess the demand and supply of transport, the availability and suitability of space, the costs and benefits of the BRT system, and the potential impacts and outcomes of the BRT system on different groups and sectors.
- Design and implement the BRT system according to the best practices and standards of BRT, such as dedicated and segregated lanes, high-capacity and accessible buses, smart and integrated fare collection, intelligent transport systems, and attractive and comfortable stations.
- Coordinate and integrate the BRT system with other modes of transport, such as metro, rail, or pedestrian facilities, to enhance the convenience and coverage of the transport network. These provide seamless and affordable intermodal transfers, and a single ticketing and information system could also be explored.
- Engage and consult with the stakeholders, such as the potential users, affected groups, informal transport operators, civil society, media, and political parties, to ensure their support and participation in the planning and implementation of the BRT system. Address their needs and concerns, and provide adequate compensation, integration, or support for those who may lose out or face challenges from the BRT system.
- Monitor and evaluate the performance and impacts of the BRT system, and make adjustments and improvements as needed. Using indicators and data to measure the efficiency, quality, accessibility, affordability, and environmental and social outcomes of the

BRT system. Soliciting feedback and suggestions from the users and stakeholders and incorporate them into the BRT system.

- Establish and participate in international platforms for knowledge exchange among cities implementing BRT systems. Learning from each other's successes and challenges fosters innovation and accelerates the adoption of best practices.
- Collaborate on developing sustainable funding models for BRT implementation. Sustainable funding is critical for the successful planning, construction, and maintenance of BRT systems.

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