Electrifying Bus Rapid Transit (BRT) Systems in Developing Regions

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About

This paper has been prepared by the Urban Electric Mobility Initiative. This analysis contributes to the assessment of international demonstration and replication opportunities for electric Bus Rapid Transit systems.

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Title

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List of Acronyms

Acronym	Meaning
BRT	Bus Rapid Transit
CNG	Compressed Natural Gas
CO2	Carbon Dioxide
GHG	Greenhouse Gas
NOx	Nitrogen Oxides
e-BRT	Electric Bus Rapid Transit
IFC	International Finance Corporation
IPCC	Intergovernmental Panel on Climate Change
IEA	International Energy Agency
ITF	International Transport Forum
ITDP	Institute for Transportation and Development Policy
NDC	Nationally Determined Contribution
UITP	International Association of Public Transport

Abstract

The electrification of Bus Rapid Transit (BRT) systems presents a critical opportunity to enhance urban transport sustainability in developing regions. BRT systems, designed to deliver high-capacity, cost-effective, and efficient public transportation, are increasingly being considered for electrification to reduce greenhouse gas emissions and improve urban air quality. This paper examines the current state of BRT systems in developing countries, the role of electric buses, and the potential benefits and challenges associated with their adoption.

The transition to electric BRT buses requires a combination of strategic planning, infrastructure investment, and financial models that address high upfront costs, charging infrastructure, and operational constraints. Various electrification strategies—including depot charging, opportunity charging, and in-motion charging—are explored in terms of their implications for service reliability, energy efficiency, and operational flexibility.

The study highlights case studies from Bogotá and Jakarta, where innovative financing models, strong political commitments, and phased implementation strategies have facilitated the transition to electric BRT fleets. It underscores that while challenges such as grid capacity, fleet management, and technological adaptation persist, well-planned electrification can significantly contribute to urban transport decarbonization.

This paper provides insights into best practices, policy recommendations, and investment strategies necessary to scale up electric BRT adoption in developing economies. By leveraging electrification of BRT systems, cities can accelerate the thrust towards lower emissions, improved air quality, and enhanced public transport services, ultimately contributing to broader climate and sustainability goals.

Introduction

Overview of BRT Systems in Developing Countries

Bus rapid transit (BRT) systems are bus-based systems that comprises performance-uplifting features that add to a high-capacity and performant bus-based system (Bennessar & Grazian, 2023a). They are designed to provide fast, reliable, high quality, safe, and cost-effective transportation, similar to urban metro systems. Key features include: dedicated right of way, off-board fare collection, intersection treatments, platform-level boarding (ITDP, 2014).

The term BRT was first introduced in the 1937 Chicago Plan to describe express bus operations in major highways that are combined with on-street distribution in the central areas in Chicago (Levinson et al., 2003). Since then, the concept has been adopted in many cities globally. At least 191 cities/regions have established BRT systems globally, moving 32 million passengers per day (ITDP, n.d.). Five hundred sixty-five (565) lines are either existing or being planned (Freemark et al., 2024), totalling more than 7,500 route kilometres (Figure 1).

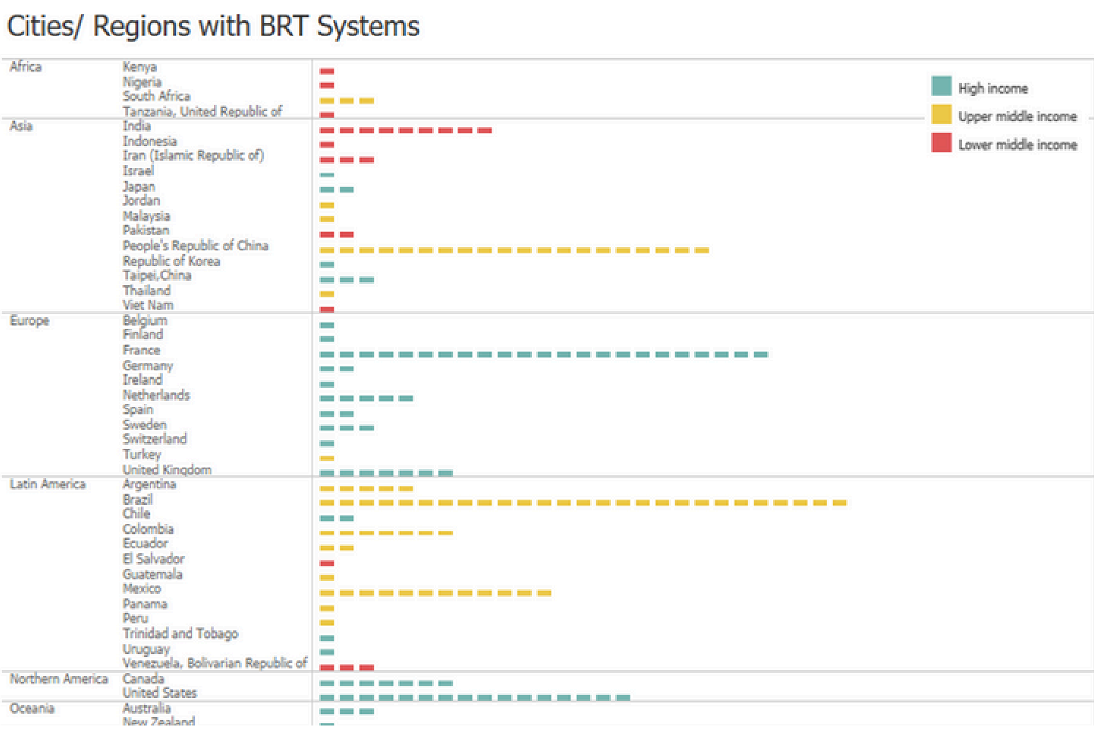


Figure 1. Number of BRT Systems Across the Globe
Source: Own analysis using data from Freemark et al. (2024)

In terms of geographical distribution, more than a third of the cities which have BRT systems are in Latin America, while Europe accounts for a fourth of the cities. Asian cities account for the other fourth, but 60% of these cities are in China (20 cities), and India (9). North America accounts for 12% of the cities. Out of the 45 countries which have BRT systems, 22 of them only have 1. Brazil hosts the highest number of BRT systems at 27.

While BRT systems are intented to offer high-capacity services at lower costs, their adoption in developing countries has not progresses as rapidly as in high income countries. Only 12% of the cities (23) that have BRT systems are in lower middle-income countries (hereinafter will also be referred to as developing countries), with 16 of the cities being in the Asian region (Table 1).

Table 1. Cities in Developing Countries with BRT Systems

Country	Cities
El Salvador	Gran San Salvador
India	Ahmedabad, Amritsar, Bhopal, Hubbali-Dharwad, Indore, Jaipur, Pune – Primpi- Chinchwad, Rajkot, Surat
Indonesia	Jakarta
Iran	Isfahan, Tabriz, Tehran
Kenya	Nairobi
Nigeria	Lagos
Pakistan	Islamabad- Rawalpindi, Lahore
Tanzania	Dar es Salaam
Venezuela	Barquisimeto, Caracas, Merida
Viet Nam	Hanoi

In terms of fleet size, 43% of the total 35 thousand BRT buses globally are in developing countries. Based on the available data, 60% of the BRT buses in cities in developing countries are standard buses, 30% are articulated, 9% are bi-articulated, and 1% are double-decker buses. In lower middle-income countries, standard buses dominate more, constituting 67% of the BRT bus fleet, while articulated ones account for the remainder.

Growing Role of Electrification in Sustainable Transport

The transport sector contributes 23% of the global CO_2 emissions from fuel combustion (Jaramillo et al., 2022). In 2023, transport-related CO_2 emissions hit a record 6.8 billion tons. Half of the transport emissions were emitted by high-income economies, while the upper middle-income economies accounted for 33%. The lower middle-income economies emitted 16%, and the remaining 1% is from the low-income economies (Figure 2).

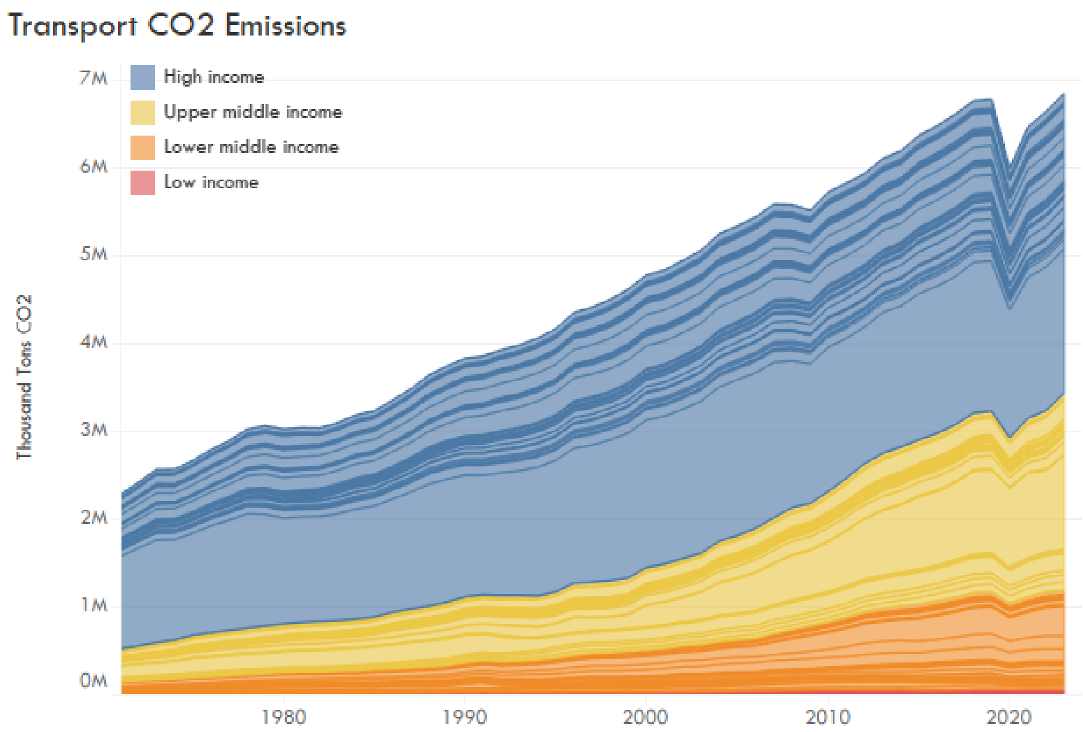


Figure 2. Transport CO2 Emissions
Source: Own visualization using data from EDGAR (European Commission. Joint Research Centre. & IEA., 2024).

Notably, between2022 and 2023, the transport sector recorded the highest emissions growth among all sectors globally, with a year-on-year increase of 3%. The International Energy Agency (IEA) estimates that over 90% of the total transport emissions in developing countries are from road transport (IEA, 2024b). Heavy-duty vehicles–buses and trucks— are estimated to contribute around 35% of direct CO2 emissions from road transport (IEA, n.d.).

Urban transport is said to contribute around half of the total transport emissions globally (International Transport Forum, 2021). Investing in high quality (and integrated) public transport systems is one of the key strategies towards mitigating GHG emissions and air pollution in highly dense cities. The lack of such integrated systems can further aggravate congestion in the future, particularly in developing countries, where the motorization rates are still relatively low. The lack of comfortable, reliable, and affordable public transport systems is a key issue that needs to be addressed in rapidly developing cities.

The Intergovernmental Panel on Climate Change (IPCC) 6th Assessment Report, states with high confidence that electric vehicles have significant potential to reduce greenhouse gas emissions from land-based transport on a life cycle basis. While the adoption of electric vehicles — including buses— has been increasing as vehicle and battery costs decline, substantial investments in supporting infrastructure are still required.

The International Energy Agency (IEA) that, under a net zero emissions scenario, transport sector emissions would slightly exceed 5.5 gigatons by 2030, down from 7 gigatons in 2020. By 2050, such a net zero scenario would require that the transport sector emit only 0.7 gigatons, or 90% reduction as compared to 2020 levels (IEA, 2021). The IPCC on the other hand (IPCC Working Group III, 2022) estimates that a 1.5-degree scenario would require reducing total transport emissions to 2 to 3 gigatons by 2050. ITF (2023) on the other hand, proposes that a high ambition scenario - wherein current mitigation commitments are accelerated – would lead to reducing the overall transport emissions to 1.6 gigatons by 2050. The decarbonisation of the sector in the net zero emissions scenario relies on a combination of policies that promote modal shifts, improvements in energy efficiency, and more efficient operations. IEA postulates that decarbonisation is dependent on two major technological transitions: electrification, and low carbon fuels.

The IPCC, since its fifth assessment report, has emphasized the importance of electromobility for land transport as a key mitigation strategy towards achieving global climate goals. In its sixth assessment report, the IPCC reiterates that widespread electrification of the transport sector is likely crucial for reducing emissions from the transport sector. It highlights that battery electric vehicles (BEVs) powered by low-carbon electricity have lower lifecycle GHG emissions than internal combustion engine vehicles (BEVs). Moreover, BEVs have the additional benefit of supporting grid operations (e.g. electric vehicle – grid integration strategies) ((Jaramillo et al., 2022).

Electrification of Buses

The global shift towards electric buses is accelerating. The IEA estimates that around 50 thousand electric buses were sold globally in 2023, increasing the total electric bus stock to around 635 thousand (IEA, n.d.). Of the electric buses sold in 2023, ninety-four percent (94%) were battery electric, while fuel cells and the plug-in hybrids models each represented roughly 3% of sales.

Countries such as Norway, Belgium, Switzerland, and China have sold more electric buses in 2023 than conventional diesel ones. In other countries such as Canada, Chile, Finland, Netherlands, Poland, Portugal, and Sweden, at least 20% of the 2023 bus sales were electric ones (IEA, 2024a). On the other hand, the

the total electric buses sold, only equates to around 3% of the total bus sales in 2023 (Figure 3).

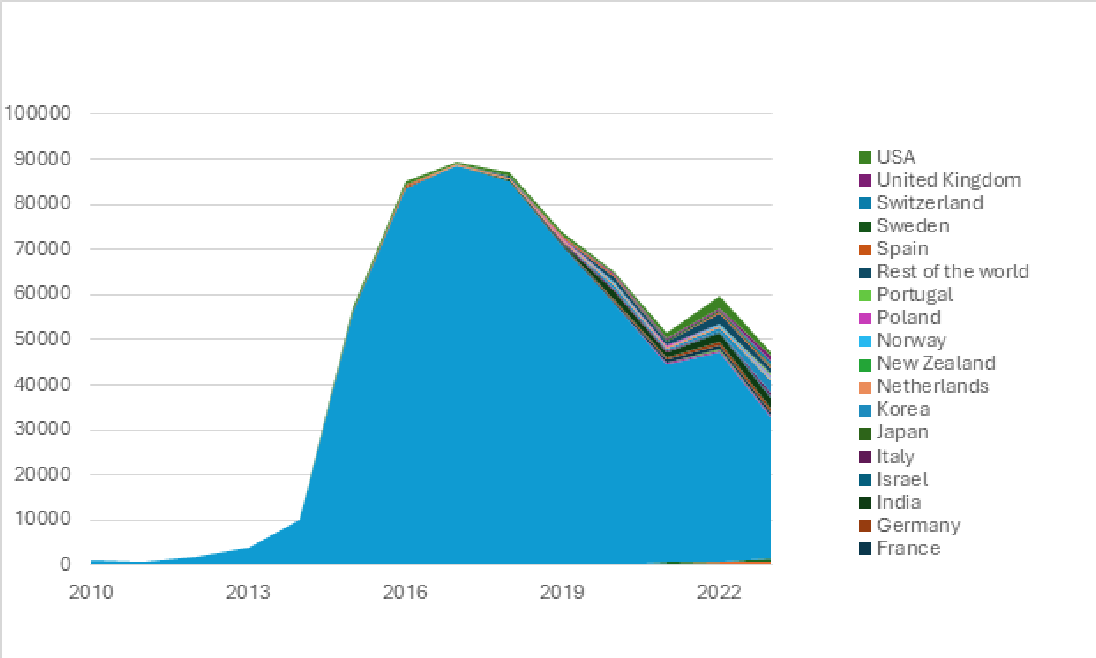
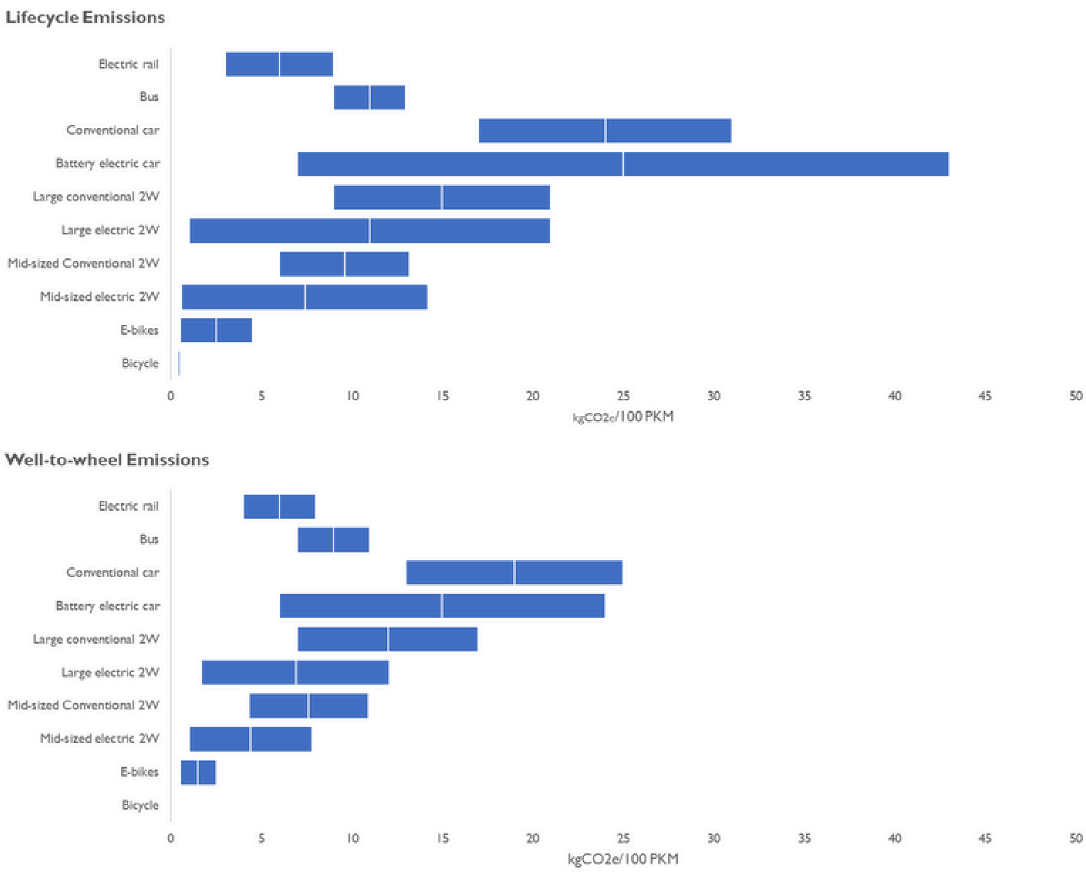


Figure 3. Electric Bus Sales
Source: Own visualisation using data from IEA (IEA, 2024a)

Wider Impacts

One of the key environmental benefits of bus electrification is the reduction—or, in the case of pure electric buses, the elimination— of tailpipe emissions. Since carbon emissions from transportation are primarily a function of the fossil fuels consumed, electric buses can significantly reduce, or nearly eradicate, well-to-tank carbon emissions (including those generated by power production), particularly when electricity is sourced largely from renewables. The same principle applies to air pollutant emissions: Replacing conventional fossil-fuelled buses with electric models remove criteria air pollutants from the tailpipe, leading to improved urban air quality. This, in t urn, has direct health benefits, such as reduced respiratory illnesses and fewer premature deaths. Additionally, the adoption of cleaner buses may have multiplier effects as more people may be attracted towards using the service. On a lifecycle-basis, electric vehicles powered by low-emissions electricity offer the largest decarbonisation potential for land-based transport (IPCC, 2022). Weiss et al. (2015) provides an overview of the ranges of emissions associated with different vehicle types, including buses based on existing literature.

It is evident that electric buses can provide significant emissions savings particularly in comparison with private four-wheeled vehicles (Figure 4).



FFigure 4. Life Cycle and Well-to-Wheel Emissions- Various Vehicle Types
Source: (Weiss et al., 2015)

However, the potential emissions reduction benefit from electric buses may not necessarily be reaped if the grid is primarily served by fossil fuels. There could be significant trade-offs, and there are also risks that the overall emission load would be higher. However, tailpipe emissions are still reduced/eliminated which still benefits the local citizenry. Also, dealing with pollutant emissions are relatively easier at point sources, such as power plants, as compared to multiple units of mobile sources.

Figure 5 below illustrates the potential impacts of transitioning to e-buses, presenting the percentage change in emission factors against fossil-based buses. The left chart is calculated for a city wherein the electricity is generated through 80% renewable energy, while the one on the right reflects a city which has less than 30% renewable energy power generation.

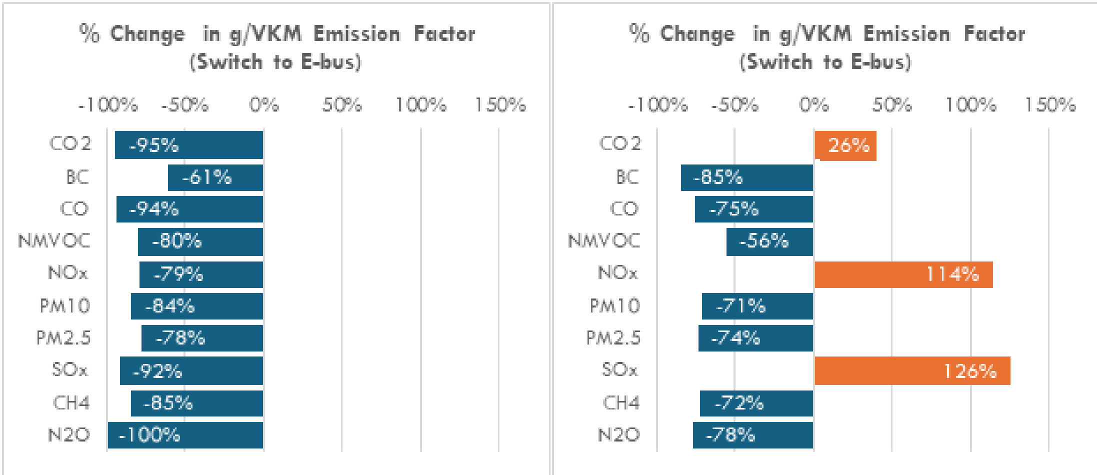


Figure 5. Change in Emission Factor (gram pollutant per vehicle kilometer)
Source: Own analysis using data from TUMI

Urban noise pollution is also reduced as e-buses are significantly quieter than the traditional diesel buses which then leads to higher quality of life.

The greatest impact from the immediate electrification of BRT systems would be represented by the lower right quadrant, which represents systems with the largest bus fleets that are currently served by electricity grids cleaner than the average. Most of them are essentially in Latin America (Figure 6).

The BRT systems on the upper right represent those that have large fleets but are being served by relatively emissions intensive electricity grids and can also be treated as critical opportunity areas to work in in terms of cleaning up electricity grids.

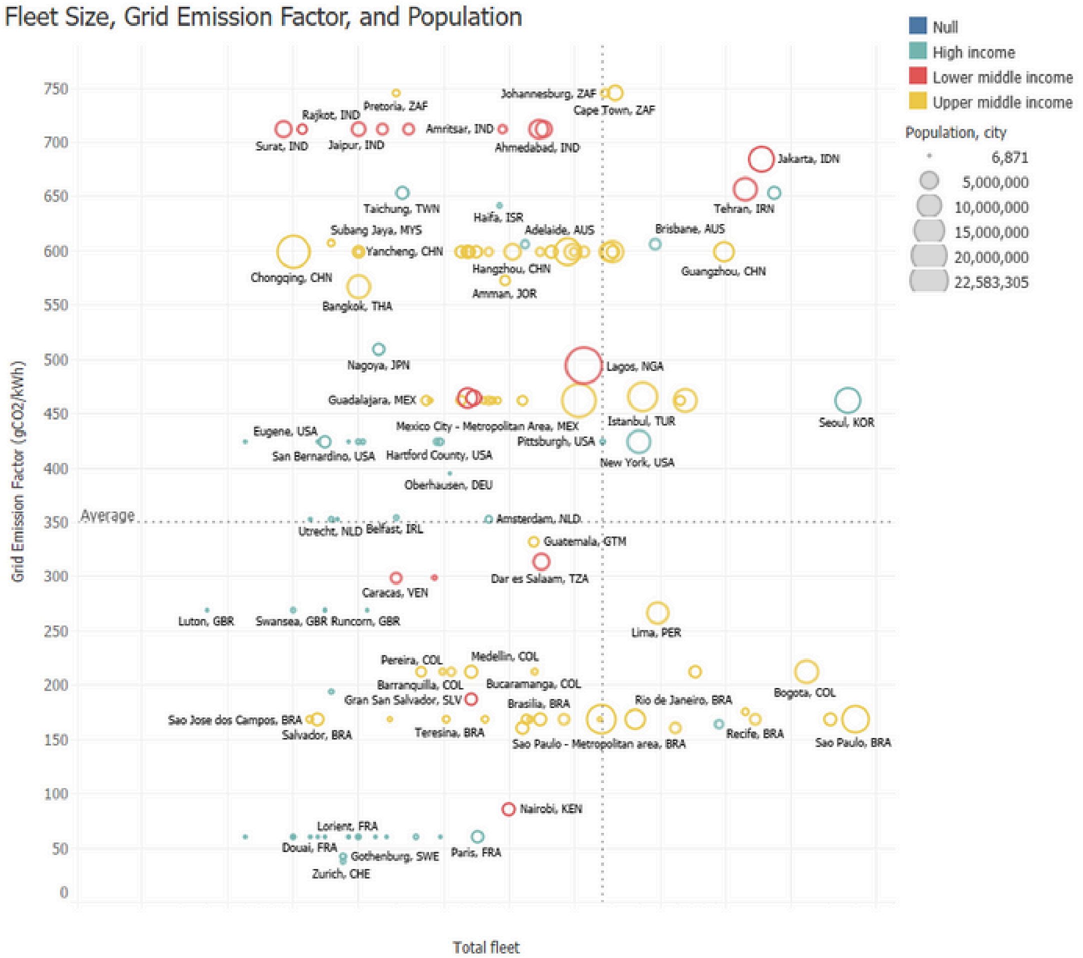


Figure 6. BRT Fleets and Grid Emission Factors

The electrification of BRT systems—especially when considering the potential snowball effects due to improved quality of service translating into increased ridership—can enhance cost-effectiveness and improve accessibility. Furthermore, the widespread adoption of BRT systems may also contribute to better road safety if accompanied by broader systemic changes. Overall, the livability of the cities served by e-BRT systems can be substantially improved.

Electric Buses in BRT Systems

Potential Market in the Developing World

The standard buses in developing countries are still mainly composed of diesel buses (82%) and CNG buses (12%). Those running on diesel/biodiesel & electricity are at 2.3%, while pure electric ones constitute only 0.3% of the BRT fleet in developing countries (Embarq, 2025). Among articulated buses in developing countries, 74% operate on diesel and 18% on CNG. Bi-articulated buses are essentially composed of diesel and biodiesel ones. Current manufacturing capacities— as demonstrated by the historical sales of electric buses— are more than sufficient to support a transition from diesel to electric, if existing BRT fleets in developing countries are considered (Figure 7).

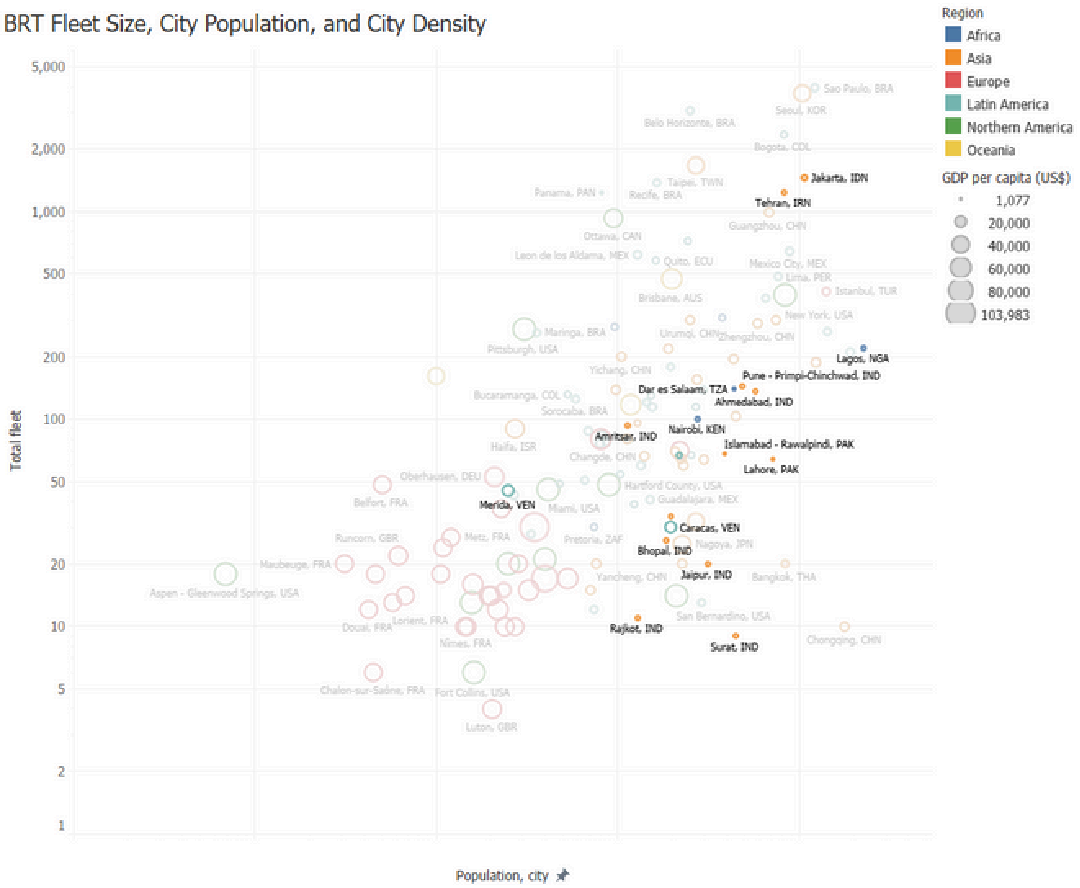


Figure 7. BRT Systems in Cities Across the Globe
Source: Own visualization using data from (Embarq, 2025)

Key Considerations

The integration of electric buses in BRT systems requires a paradigm shift in terms of the operations of these systems. Electric buses can vary in terms of the degree of electrification, depending on the configuration of the propulsion system: hybrid electric (series and parallel), battery electric, fuel cell electric (Mahmoud et al., 2016), and their inherent characteristics also impact their integration into BRT systems. The adoption of electric buses in existing BRT systems will impact bus system planning and need a comprehensive approach which involves not just a focus on the vehicles, but also in terms of service operation design, and charging infrastructure (Bennessar & Grazian, 2023a).

One key determinant of the impacts of electric buses on BRT systems is the modality for charging the buses. The table below summarizes the different types of charging strategies and what their impacts might be on the operations of the BRT:

Depot Charging

Depot charging is also referred to as overnight charging Depot charging—as the name implies— is done through dedicated depots which can accommodate the simultaneous charging of multiple bus units. It is typically associated with slow charging at a low power, wherein charging can last between 4-8 hours. They utilize plugs, or pantographs. These long charging times would reduce the flexibility (e.g. mid-day deployment (Bennessar & Grazian, 2023b). Changes in labour requirements (e.g. additional night-time personnel) might also be necessary.

Figure 8 . Charging an E-bus in a Depot

From an operational perspective, scheduling is straightforward, as charging typically occurs during off-duty hours. However, longer-ranger routes require larger battery capacities. Regarding infrastructure, significant space is needed for depots, which entails substantial initial investments and can create spatial constraints.

As charging is also usually done during off-peak hours (such as overnight), it has low impact on the power grid. This would typically result in lower operational costs as off-peak rates would apply.

Opportunity Charging

As the name implies, "opportunity" charging makes use of the fast-charging opportunities within specific locations in the network. For example, line end-stops, terminals, depots, and charging hubs (Estrada et al., 2017). They typically requite pantographs or inductive pads, with charging times ranging from 5 to 20 minutes. Typical power outputs can range from 150 to 600 kW; when the output exceeds600 kW, the systems are generally referred to as flash charging facilities, allowing charging to occur within the dwelling times at the bus stops.

Figure 9. Charging Pad for Buses Example
Source: (Zukowski et al., 2024)

Opportunity charging requires smaller battery sizes. From a vehicle perspective, the smaller batteries allow for higher passenger capacities, but real-time monitoring systems are required. Battery replacement costs could be lower due to the smaller batteries.

High voltage grid connections are also needed at the locations, which would entail significant infrastructure costs. On the other hand, while the introduction of charging will impact the scheduling, it allows for the integration of the electrification aspect within a continuous service through frequent top-ups.

On-route Battery Swapping

This entails that batteries are swapped at dedicated stations for a few minutes, typically within 5 minutes. This modality would result in minimal downtime and allows for full-day operations without the need for long charging breaks.

On the other hand, swapping facilities, as well as standardized battery systems are needed, which entail costs. There are also associated risks related to logistical complexities, and are not widely used in the BRT sector, but there are deployments for public buses.

In-motion Charging

This system enable continuous charging through overhead wires, with battery backup for those sections that are not covered by the wires. In essence, the bus ranges in these systems are primarily a function of the wired sections and can provide high reliability for fixed-route BRT systems. As the system is depended on the wired network, significant upfront costs are entailed, but lower operational costs can be reaped. Its infrastrcture requirements are similar to those of light rail systems (LRT) and offers limited flexibility for route changes.

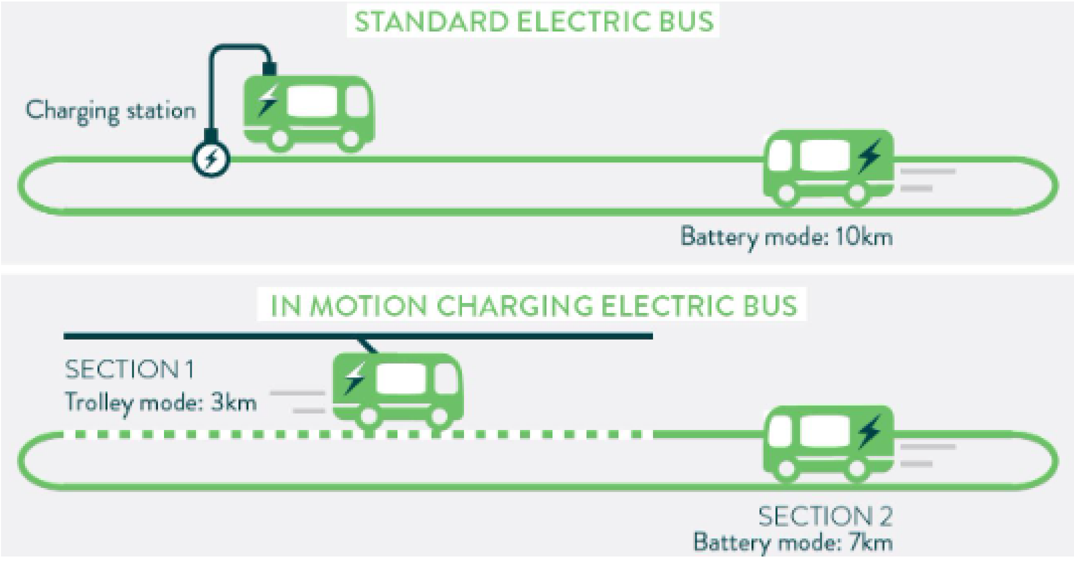


Figure 10: In Motion Charging
Source: (UITP, n.d.)

Box 1. Using the BRT Standard – How E-buses can Impact BRT Systems

BRT Basics

The "basic" components of a BRT corridor—based on the BRT Standard— are:

- Dedicated right-of-way – dedicated lanes for separating BRT buses from other vehicle traffic
- Busway alignment – should ideally be in areas where conflicts with other vehicles are minimized
- Off-board collection – essential in reducing travel time and ensuring good customer experience
- Intersection treatments – measures such as traffic signal priority for BRT buses.
- Platform level boarding – essential in the speed of boarding and alighting.

The utilization of electric buses in BRT corridors will not directly impact these elements as compared to systems that use conventional fossil fuel -based buses.

Service Planning

The introduction of electric buses in BRT corridors will affect service planning.

For multiple routes— such as those operating over several — the upfront costs associated with the electric buses and their charging infrastructure may limit the overall network coverage.

Control centres need to be upgraded to properly account for the state of the e-buses, particularly the state of charge of the buses.

Peak frequencies can be affected if charging cycles would disrupt the operations. Opportunity charging and flash charging can avoid such issues but would require significant costs. Electric buses—which have better acceleration—can be more appropriate for express services.

Depending on the charging modalities, the hours of operation can negatively be impacted. For example, long charging times can reduce bus availability in a 24-hour service network. On the other hand, indirect positive impact in terms of "integration with other transit" can result from the use of e-buses due to improved branding.

Stations

E-buses produce no tailpipe emissions, which significantly improves air quality within BRT stations.

Improved air quality, and reduced noise will enhance passenger comfort, and safety. In case where opportunity charging schemes will be adopted, provisions for charging equipment would need to be integrated into the layout of the stations. Additionally, station spacing during the planning phase should take opportunity charging requirements into account.

Communications

The use of electric buses within BRT systems presents an opportunity to enhance the system's public emphasizing its environmental benefits. The eco-friendly aspects of electric buses can also create new marketing opportunities and attract additional passengers, for instance, by positioning the buses as platforms for green advertising.

opportunities and attract additional passengers, for instance, by positioning the buses as platforms for green advertising.

Access and Integration

Electric buses, as they greatly reduce noise pollution, and air pollution, can have positive impacts in terms of integrating with non-motorized networks.

BRT Service Planning and Operations

A closer look at the potential impacts of the utilization of electric buses in BRT service and planning operations is provided in Table 2 below.

Table 2. Potential Impacts of Electric Buses in BRT Systems

	Key Considerations	Potential Impacts
Service planning and operations		
Route design and scheduling	Diesel buses—due to quick refuelling times—offer more flexible scheduling	• Charging times and windows need to be incorporated in the scheduling • Routes must be designed in accordance with the limitations set by the charging times and range limitations • Integration of new components in existing facilities might be needed depending on the characteristics of the e-buses to be employed • Potential reduced operational flexibility and service interruptions.
Vehicle range	Depending on the battery size, load and climate conditions, ranges are determined	• Longer routes could potentially require higher capacity batteries; infrastructure for opportunity charging.
Vehicle torque	Electric buses deliver instant torque	• Improved performance in routes with frequent stops, steep gradients, or congested areas.

Ride quality	Electric buses generally offer quieter operations, and reduced vibration which would play a role in the provision of service quality	• Better experience for the users in terms of ride quality
Energy costs	Electricity costs are generally more stable than diesel prices	• Lesser energy cost fluctuations make operations cost more predictable and more reliable financial planning
Infrastructure		
Depot charging	Significant space needed for depot charging	• Significant capital requirements • Existing depots would need to be retrofitted, expanded or relocated
On-route	Installation of opportunity chargers or pantograph systems at key locations	• Financial costs associated with the installation of the chargers • Vis-à-vis depot charging, smaller batteries would be needed but real time monitoring systems are required

In-motion	Overhead wires required	• Financial costs associated with the installation of the wired network • Difficult to implement route changes
Maintenance and Fleet Management		
Maintenance complexity	E-buses have fewer mechanical parts, but employ battery systems, electric motors, power electronics	• Reduced frequency for maintenance related to mechanical parts • Requires specialized skills which may trigger retraining or changes in staff requirements • Advanced monitoring systems can reduce downtime
Battery lifecycle	Batteries can last up to 6-8 years, depending on the influencing factors	• Managing battery degradation is crucial • Battery disposal needs to be integrated in the plans • Second life applications (utilization of the batteries as stationary energy storage) need to be considered
Financial Management		

Capital expenditure	E-buses and the associated infrastructure have high upfront costs	• High financial burden at the start of the transition
Revenues	Impact on passenger capacities	• Depending on the modalities, there could be impacts on potential passenger capacities. For example, depot charging would require larger batteries, thus heavier loads, and therefore might adversely impact peak passenger capacities of the buses.
Operating costs	Changes due to inherent characteristics of e-buses	• Routine maintenance costs are reduced • Energy costs per kilometre are reduced • Less fluctuations in the energy costs • Battery replacement is a significant operational cost item • End of life considerations are also important. They can incur costs, or can also result in further

		savings (e.g. in the case the batteries are used as on-site energy storage systems)
Business models	Innovation needed to lower financial risks and tap into new fund streams	• Carbon credits and climate-related funds can provide additional revenue streams • Potential need to revise asset ownership, as well as operational and maintenance contract • Potential need for new business models to enter the BRT ecosystem (e.g. battery leasing)
Workforce		
Driver training	Potential vehicle characteristics featuring regenerative braking, battery management	• Driving style adaptation to maximize range • Capacity building needed
Maintenance staff	Involvement of new system components and features	• Mechanics need upskilling to properly handle high voltage systems, as well as diagnostics software • Potential new additions to maintenance staff

Safety protocols	New protocols should be instituted	• Establishment of protocols (and associated trainings) on batteries and high-voltage systems

Service quality

The delivery of high-quality bus services plays a major factor to make people to use public transport. The concept of service quality is multi-dimensional, and the relative importance of the attributes may vary in different contexts. Service quality is a set of service attributes that are defined by transport operators and collected from users to measure satisfaction (Hensher, 2015). The gap, between service provided and perceived, has an important link to maintain loyalty and acquire new users.

To narrow the gap and increase the number of public transport users, transit authorities and operators identify what passengers desire from public transport service and what passengers have experienced from current service. BRT systems, while generally considered more convenient than traditional bus services, they are generally viewed more less attractive than personal means of transport, compared to personal means of transport (Cao et al., 2016 as quoted in (Saleem et al., 2023).

Enhancing service quality is not only about understanding service from the perspective passengers but also acknowledging the desired quality from them (Dell'Olio, et al., 2011). Service quality attributes such as comfort, safety, convenience, timeliness, and reliability have constantly been identified in relevant studies as important attributes for the bus customers (Li, et al., 2018). Dell’Olio et al. (2011) suggests that waiting time, cleanliness and comfort are the attributes the current users value the most. While, waiting time, journey time and crowding level are the three main attributes the potential users consider (Table 3).

Table 3. Service Quality and Potential Impacts of E-buses

Service Quality Dimension	Potential Impacts of E-buses
Operating speed	There could potentially be negative impacts with depot charging as heavier batteries could be needed and can thus result in lower operating speeds due to heavier loads.
Operating frequency/waiting time	Depot charging may result in the reduction of bus availability particularly during peak hours due to long charging times. Opportunity charging, in route, or flash charging can maintain high operating frequencies, but can come with higher capital costs, and infrastructure/equipment integration.
On-time performance	There are risks associated in case charging delays occur. Flash charging can slow down in case the charging times would need to overlap with the dwell time.
Headway	Opportunity charging and flash charging can maintain short headways.

Peak hour passenger load	Buses using depot charging could limit the number of buses due to the space and weight requirements of the bigger batteries.
Service span	Service span may be impacted in the case of depot charging. Opportunity charging may maintain similar base services but may require additional labour requirements.

Challenges and Success Factors

While the integration of electric buses into public transport systems is gaining traction, the transition needs to be more than just the replacement of vehicles, and this holds true for the electrification of BRT systems.

To narrow the gap and increase the number of public transport users, transit authorities and operators identify what passengers desire from public transport service and what

Challenges

General Challenges with Electric Buses

High Upfront Costs

One of the main challenges towards the integration of electric buses in BRT systems—and in any bus fleets—are the high upfront capital costs.

While there have been recent studies that indicate that the total life cycle costs for electric buses can compete (or are even lower) with diesel buses, the upfront costs of procuring e-buses and the associated charging equipment is still prohibitive, particularly in developing countries.

For example, the life cycle cost study comparing diesel and electric buses in Nepal (Rijal & Thapa, 2023) estimates that that at the end of 10 years, the lifecycle costs of diesel buses are roughly the same as the diesel buses. However, this analysis includes the environmental costs due to CO2. While the energy/fuel costs for the e-bus are only less than a fourth of those for the diesel bus, the diesel buses.

However, this analysis includes the environmental costs due to CO2. While the energy/fuel costs for the e-bus are only less than a fourth of those for the diesel bus, the diesel bus unit itself is less than a fourth of the price of the electric counterpart.

A similar study conducted in India found that at 25 years, the total cost of ownership of an electric bus is 5 to 10 percent lower than a comparable diesel bus. In the said study, the initial cost of the electric bus (with subsidies) is still 2.5 times the price of the diesel bus (Sheth & Sarkar, 2019). For transit authorities, and operators, immediate needs and limited budgets are critical limiting factors (IFC, 2020).

High Upfront Costs

The electrification of BRT systems would require development of depots and charging stations, resulting in in concentrated energy demand to support the charging of multiple electric buses, especially if several vehicles are charged simultaneously. Grid reliability has has become a major concern in developing regions as Latin America, Asia, and Africa driven by population growth, reliance on technology, new construction, and the impacts of climate change (G&W Electric, n.d.). Transitioning to electric buses may also pose additional complexities in terms of load management for BRT operators.

Technical Expertise

The introduction of electric buses in any bus fleets would require technical expertise to ensure smooth, safe, and economically sound transition towards electrification, a challenge that is more pronounced in developing nations.

Challenges Specific to BRT Systems Towards Integrating Electric Buses

Aside from the challenges associated with e-buses in general, there are also BRT-specific factors that need to be addressed when it comes to electrification.

BRT systems are meant to be high frequency, providing high- capacity operations

BRT systems operate at high frequencies and serve a large number of passengers each day. For existing systems, the transition to electric BRT buses requires charging solutions that do not disrupt or modify the high service frequencies. Downtime for charging, if not properly managed, can lead to service gaps.

BRT buses also operate on specific routes or corridors, which may also limit operational flexibility when deploying spare electric buses.

BRT Depots and Terminals Constraints

Depots and terminals for BRT systems are often located in highly dense urban areas. As a result, space can be a significant constraint. Many BRT depots may lack sufficient room for multiple charging points, making careful planning of the layout essential. In particular, the utilization of high-powered chargers— which are needed to reduce charging times — further increases space requirements. Aside from the space requirements, cooling considerations are also present for high power chargers which normally require dedicated cooling units.

Aside from space considerations, electrical capacities are also a constraint. Simultaneously charging of multiple high-capacity buses places considerable demand on local power grids, which many not be equipped to handle such heavy loads.

Vehicle-related Requirements

BRT systems usually operate using larger capacity vehicles, such as articulated and bi-articulated buses, to accommodate large volumes of passengers. The operational characteristics of BRT — frequent stops and rapid acceleration or deceleration — further influence vehicle performance. Incorporating batteries into these buses increases their overall weight, which can impact not only their range but also the passenger capacity and overall operational efficiency within a BRT system.

Service Reliability

BRT systems operate to achieve high levels of service reliability. Factors such as weather, passenger loads, and route typologies can impact ranges and can also lead to unexpected charging requirements during the service and can lead to service gaps.

Long-Term Planning

Implementing pilot projects with a small number of electric buses in BRT corridors is fundamentally different from scaling up to a full transition to electric BRT systems. The installation of charging systems based on current demand can lead towards much more expensive upgrade requirements in the future. Also, rapidly advancing battery technologies also pose risks related to rapid obsolescence.

Success Factors towards Integration of E-buses in BRT Systems in Developing Countries

We can look into existing case studies wherein electric buses have been tested or integrated into existing BRT systems in developing countries and distill the main success factors for such integration:

Bogota, Colombia

Instead of conducting a tender, the city decided to amend existing concession contracts with operators, replacing diesel buses with battery-electric vehicles. This strategy introduced a new stakeholder—the charging infrastructure provider—who adopted a leasing model to facilitate battery charging. Under this arrangement, operators remain responsible for supplying and managing the electric bus fleet via a comprehensive concession contract, while a separate lease agreement is established with the electricity infrastructure provider.

In 2021, Bogota also established concession contracts which involved one entity providing the buses and charging infrastructure, while another was responsible for maintenance and operation. In essence, fleet providers own the e-buses, while TransMilenio pays for the use of the buses and the buses and the services of the operators which provided flexibility for TransMilenio to take out operators that do not fulfill service quality requirements (Batista & Bastos, 2023). The fact that fleet providers sign contracts with the public entity—TransMilenio— their financial risks are lowered as guarantees are also provided.

Another strategy was that the period for the concession contracts, and the possibility to extend them, plays a big role in the integration of electric buses. The City changed the contract period for diesel buses from 20 to 10 years, and 15 years for electric buses. The longer the contract period is, the higher the chances for e-buses to become more viable against the alternative. From a wider perspective, the political support and commitment of the City to continue to subsidize the fare is also a crucial factor for the success of the system and its electrification.

Jakarta, Indonesia

The Transjakarta bus rapid transit (BRT) system, inaugurated in 2004, is the first BRT system in Southeast and South Asia that initially featured services covering 208 kilometres ((TransJakarta, n.d.)). As of November 2023, TransJakarta serves an average of 1.134 million passengers daily, indicating a significant reliance on the system (Sakina, 2023).

Transjakarta has set a goal to transition to a fullyelectric bus fleet, targeting 10,000 e-buses by 2030. This commitment is supported by the Governor of Jakarta Decree 1053/2022, which also establishes an interim target of 50% electrification by 2027 (ITDP, 2023). As of the end of 2022, there were 52 e-buses in operation, and 46 additional ones were expected in 2023 (Triatmojo et al., 2024).

There is a strong political basis for the electrification goals of TransJakarta. The Jakarta Special Capital Region (DKI Jakarta) provincial government plans to expand public transportation and accelerate the transition to electric vehicles as part of its strategy to cut economy-wide emissions by 50% by 2030.

In 2019, the Jakarta Government partnered with C40 to develop a Climate Action Plan (CAP) in line with the Paris Agreement.

As part of the Fossil-Fuel-Free Streets Declaration, the city committed to: (1) exclusively procuring zero-emission buses beginning in 2025, and (2) making most of Jakarta's city center emission-free by 2030. There were subsequent government instructions (90/2021; 91/2021) issued by the Jakarta Government to expedite the procurement of electric buses for a pilot project, and to establish a net zero emissions target by 2050 (ITDP, 2023).

At the national level, the Ministry of Industry and Finance announced direct financial incentives for the procurement of 138 e-buses, as well as VAT reduction for e-buses that meet a minimum local manufacturing content of 40%.

Indonesia's nationally determined contribution (NDC) under the Paris Agreement forms the foundation of its climate **commitments**, targeting a reduction in greenhouse gas (GHG) emissions by 29% unconditionally and up to 41% with international support by 2030. Presidential Regulation (PERPRES) 55/2019, which focuses on accelerating the adoption of battery electric vehicles (BEVs), plays a key role in supporting the country's broader transition from fossil fuel-based transportation to cleaner alternatives. (Asian Transport Outlook, 2023).

To incentivize EV adoption, **purchases are exempt from several taxes**, including the luxury sales tax, which typically ranges from 15% to 40% for internal combustion engine (ICE) vehicles.

Comprehensive trials involving electric buses were conducted between to assess the performance of the e-buses within the BRT system. For example, a 423-day trial was conducted to assess the energy consumption, as well as the operational performance, and potential environmental impacts of the e-buses. Detailed energy consumption and requirement studies for specific routes have also been conducted incorporating local drive cycles, passenger loads, distances were considered. These played a role in identifying certain routes which are suited for short-term transition to e-buses without significant operational changes (Triatmojo et al., 2024).

The results of the trial were then used to assess the potential for scaling-up and had resulted in the adoption of the targets.

A **training needs assessment** survey was also conducted to pinpoint priority training needs in the integration of e-buses in Transjakarta as illustrated in Figure 11.

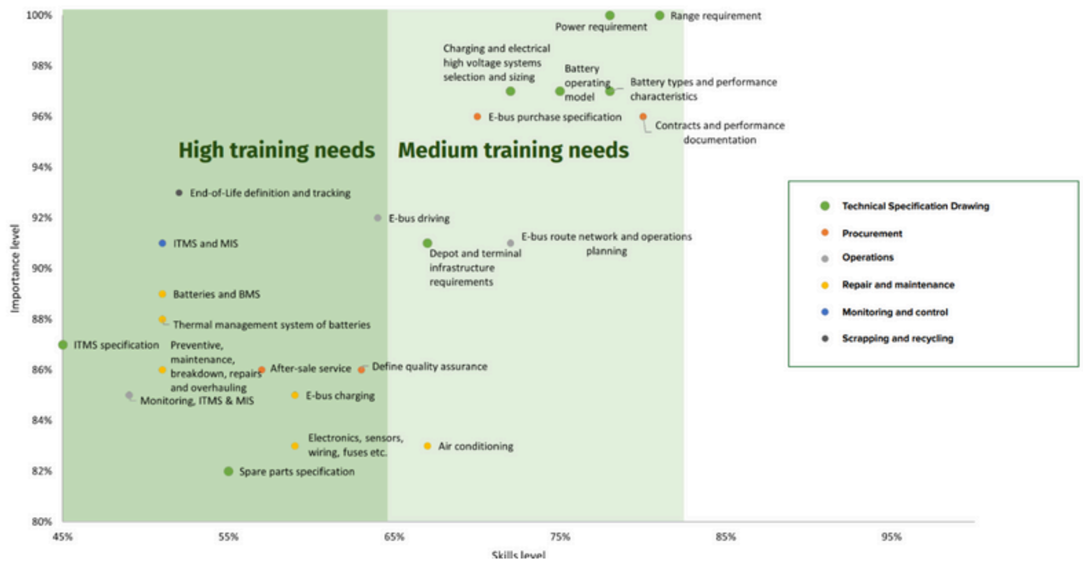


Figure 11. Training Needs Assessment Results for Transjakarta
Source: (ITDP, 2023)

Success Factors towards Integration of E-buses in BRT Systems in Developing Countries

A critical factor—as in the case of Bogota—is the adoption of new business models that separate asset ownership from operations. Traditionally, BRT operators were responsible for procuring, operating, and maintaining their fleets, but the transition to electric buses required a shift to segregated asset ownership models.

This approach enables financial risk mitigation by introducing separate concession agreements: one for fleet provision and another for operations and maintenance.

In Bogotá, this model involves a charging infrastructure provider that leases battery charging services, ensuring a financially sustainable arrangement. In Jakarta, fleet providers sign direct contracts with the government, benefiting from guarantees that lower investment risks. These models ensure operational flexibility while leveraging the expertise of multiple stakeholders.

Financial and contractual arrangements are pivotal to the viability of electric buses. Adjustments to contracts to reflect the cost structure of electric buses in local conditions are critical. For example, Bogotá introduced longer contract durations for electric buses— 15 years compared to 10 years for diesel buses — to enhance financial feasibility.

A strong policy and regulatory framework are key drivers of this transition. Both cities have set ambitious electrification targets, supported by local and national policies. Bogotá has developed a long-term roadmap for zero-emission fleets, incorporating progressive investment calls and strategic amendments to existing contracts to phase out diesel buses. In Jakarta, the electrification strategy is integrated into broader climate commitments, such as the Fossil-Fuel-Free Streets Declaration and the Jakarta Climate Action Plan, both of which require the city to procure only zero-emission buses from 2025 onward.

Additionally, Indonesia's Nationally Determined Contribution (NDC) under the Paris Agreement and Presidential Regulation 55/2019 provided a strong national-level push for accelerating battery electric vehicle (BEV) adoption.

Beyond policy and finance, data-driven decision-making and pilot programs have been instrumental in scaling up electric bus deployment. Both cities conducted comprehensive trials to evaluate operational feasibility, energy consumption, and environmental impacts. In Jakarta, for example, a 423-day trial included route-based feasibility studies that analyzed drive cycles, passenger loads, and distances to identify optimal deployment strategies.

Training needs assessments were also carried out to prepare operators and technical staff for the transition. These evidence-based approaches have ensured that electrification strategies are tailored to operational realities, reducing risks and ensuring a smoother integration process.

Ultimately, the successful electrification of BRT systems in Bogotá and Jakarta has been driven by a holistic approach that brings together financial innovation, strong policy commitment, and strategic planning. By aligning business models, incentives, regulatory frameworks, and data-driven insights, both cities have made significant progress toward zero-emission on public transport while ensuring the long-term sustainability of their systems.

Summary

The electrification of Bus Rapid Transit (BRT) systems in developing regions presents a transformative opportunity to enhance urban mobility while contributing to global decarbonization efforts. This document examines the growing role of electrification in sustainable transport, focusing on the integration of electric buses into BRT systems.

Overview of BRT Systems in Developing Countries BRT: systems offer high-capacity, cost-effective transit solutions that mimic the efficiency of metro systems. Despite their benefits, penetration in developing countries remains limited, with only a fraction of cities adopting BRT networks. The majority of these systems are still reliant on diesel or compressed natural gas (CNG) buses, highlighting the need for electrification to meet climate goals.

The Case for Electrification: The transport sector is a major contributor to CO2 emissions, with road transport accounting for over 90% of emissions in developing countries. Electrification of public transport, particularly BRT systems, aligns with global climate commitments by reducing greenhouse gas (GHG) emissions and improving urban air quality. The shift to battery-electric buses, while promising, requires significant investments in infrastructure, grid capacity, and operational adjustments.

Key Considerations for Electrification: Integrating electric buses into BRT networks necessitates a shift in planning and operations. The choice of charging strategy—depot charging, opportunity charging, battery swapping, or in-motion charging—directly impacts scheduling, vehicle range, and service reliability. Additionally, electrification influences station design, fleet management, and financial models. Infrastructure constraints, including depot space and grid reliability, pose further challenges.

Operational and Financial

Challenges: Transitioning to electric BRT systems involves high upfront costs, particularly for vehicle procurement and charging infrastructure. While total life-cycle costs of electric buses can be competitive with diesel alternatives, financial constraints in developing regions hinder widespread adoption. Additionally, technical expertise and workforce training are crucial for maintaining electric fleets.

Case Studies: Bogota and Jakarta: The experiences of Bogota and Jakarta highlight successful approaches to BRT electrification. Bogota's TransMilenio system adopted an innovative asset ownership model, separating vehicle procurement from operations to mitigate financial risks. Jakarta, meanwhile, set ambitious electrification targets backed by strong government support and financial incentives. Both cases demonstrate the importance of long-term planning, policy commitment, and innovative financing mechanisms in advancing e-BRT adoption.

The transition to electric BRT systems is a critical step toward sustainable urban transport in developing countries. While challenges remain, strategic planning, supportive policies, and financial innovations can drive the adoption of electric buses, delivering both environmental and societal benefits. Future efforts should focus on addressing infrastructure needs, ensuring grid resilience, and scaling up electrification initiatives to maximize impact.

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