

# Introduction of E-Buses in Pakistan's Urban Centers:

Progress, Challenges and Road Ahead

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## Abstract

This paper explores the present status of electric bus adoption in Pakistan, focusing on Lahore's electric bus project as a case study. Using a mixed-methods approach and drawing from regional experiences in China, India, and Bangladesh, it assesses the environmental impacts and strategic potential of electric mobility in the public sector. The study highlights existing regulatory and infrastructural challenges, emphasizing the need for a liberalized policy regime, greater public-private collaboration, and access to international development finance. Key frameworks such as the National Electric Vehicle Policy and Pakistan's Nationally Determined Contributions (NDCs) are examined to understand their role in enabling green mobility. The case of Lahore provides practical insights into implementation barriers and policy coordination gaps. The study concludes with recommendations to expand renewable-powered charging infrastructure, promote local manufacturing to reduce import dependence, and leverage both federal development programs and global financing to scale electric bus deployment. Pakistan can learn lessons from the success of China's large-scale adoption of EV public transport systems to India's Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles (FAME) project. These steps are vital for achieving environmental sustainability, enhancing urban transport, and supporting Pakistan's transition to a cleaner, more resilient economy.

**Keywords:** *Electric Vehicles (EVs), sustainable transport, public-private*

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*partnerships, renewable energy, local manufacturing, climate policy, charging infrastructure.*

## **1. Introduction**

Air pollution costs Pakistan approximately 6.5% of its annual GDP (World Bank Group, 2022), making it increasingly important to introduce e-buses to address air pollution, urban congestion, and a growing demand for sustainable transportation solutions. The rapid urbanisation of cities such as Karachi, Lahore, and Islamabad have intensified the need for efficient, clean, and scalable public transport systems (Saleem, 2024). Traditional diesel and CNG-powered buses contribute significantly to air pollution, which has become a critical issue in Pakistan's urban centres. Major cities of Pakistan are one of the most polluted cities in the world and most of it is attributed to vehicular emissions ((Khan, 2021); (Mir, 2024)). This is observed in the fact that as of 2025, Pakistan's transport sector accounted for 25% of the country's total carbon emissions, 98% of which are accredited to the road sector. (Asian Transport Outlook, 2024)

In Pakistan, introducing e-buses is becoming increasingly important as the country faces pressing challenges related to air pollution, urban congestion, and a growing demand for sustainable transportation solutions. The rapid urbanisation of cities such as Karachi, Lahore, and Islamabad have intensified the need for efficient, clean, and scalable public transport systems (Saleem, 2024). Traditional diesel and CNG-powered buses contribute significantly to air pollution, which has become a critical issue in Pakistan's urban centres. Major cities of Pakistan are one of the most polluted cities in the world and most of it is attributed to vehicular emissions ((Khan, 2021); (Mir, 2024)).

Public transport in urban Pakistan, especially Lahore, relies heavily on diesel vehicles, contributing to pollution and emissions. While electric buses offer a cleaner alternative, their adoption faces infrastructural, financial, and policy challenges. Pakistan has an opportunity to mitigate its urban environmental challenges, like smog and worsening air quality by replacing fossil fuel transportation system with electric alternatives. Though the upfront costs of electric alternatives are higher but the economic and environmental benefits it offers can have far reaching impact on the nation's economy by reducing its dependence on fossil fuels. Furthermore, it aligns with Pakistan's vision for a greener and sustainable future by reducing carbon emissions (Asghar, 2021). Furthermore, e-buses can help reduce Pakistan's dependency on imported fossil fuels, promoting energy security and economic resilience in fluctuating global oil prices.

Adopting electric buses in Pakistan presents a strategic solution to growing urban air pollution, public health risks, and fossil fuel dependency, particularly in cities like Lahore and Karachi. This study focuses on Lahore as a pilot case

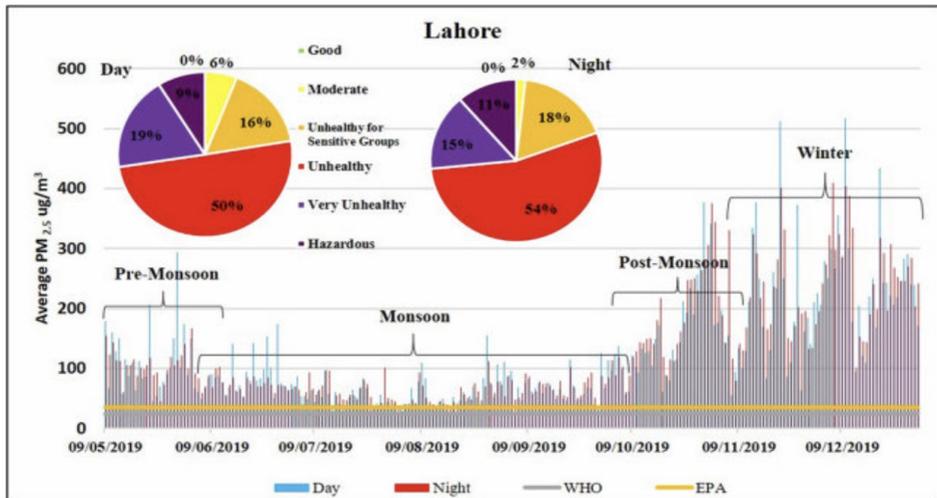
to assess the financial, technical, and environmental feasibility of transitioning to electric buses. Using a mixed-methods approach, it integrates global case comparisons, local feasibility data, and stakeholder experiences to analyze infrastructure requirements, cost sustainability, and operational challenges. Aligned with Pakistan’s National Electric Vehicle Policy, the study offers evidence-based, context-specific recommendations to inform similar urban transport initiatives nationwide.

### 1.1. Importance of E-Buses for Pakistan

Major urban cities in Pakistan are currently grappling with the existential challenge of clean air, and the rapid urbanization of cities like Karachi, Lahore, and Islamabad has heightened the need for an efficient and cleaner public transport system. According to the Urban Unit, Government of Punjab, one of the largest contributors to Lahore’s smog issue stems from vehicular emissions, which constitute about 40% of PM<sub>2.5</sub> concentrations in Lahore (Khan, 2021). Figure 1, adapted from Anjum et al. (2021) tracks the PM<sub>2.5</sub> concentrations in Lahore from 2019 to 2020, highlighting persistent high levels of pollutants that exceed the limits prescribed by WHO and EPA standards. This merits both an emergency response and long-term planning to mitigate the risks posed by the ever-growing fossil fuel-based vehicles. Public transport can effectively reduce these levels; the Lahore Orange Metro Train, with its large daily ridership, serves as a prime example. Similarly, pilot programs in Karachi and Islamabad suggest a shift in policy towards electric vehicles.

**Figure 1**

*Day and Night Average Concentrations of PM<sub>2.5</sub> (µg/m<sup>3</sup>) in Lahore 2019-2020*



Source: (Anjum, 2021)



The global lessons indicate that large-scale adoption of e-buses can offer a pathway to deal with these pressing environmental challenges, and Pakistan has an opportunity to shift its public transport system to electric alternatives by replacing confrontational fossil fuel-based transport. This unique case scenario offers an opportunity for Pakistan to reduce its urban pollution, improve worsening air quality in major urban cities, and also achieve its climate goals. Furthermore, the benefits offered by e-buses outweigh the costs in the longer run. While the initial capital costs, in terms of infrastructure upgrades and purchases, may be higher, the long-term benefits outweigh the costs (Asgar, 2021). Furthermore, e-buses can help reduce Pakistan's dependency on imported fossil fuels, promoting energy security and economic resilience in the face of fluctuating global oil prices.

## 1.2. Statement of Problem

Public transportation in Pakistan's urban centres, notably Lahore, predominantly depends on conventional diesel-powered vehicles (Awez, 2024). This dependence significantly contributes to air pollution, greenhouse gas emissions, and noise pollution (Afifa, 2024). With escalating concerns over climate change, deteriorating urban air quality, and public health risks (Hoffmann, 2021), there is an urgent need to transition to more sustainable and eco-friendly public transportation alternatives. Electric buses (E-buses) emerge as a promising solution, offering cleaner and quieter modes of transport (Kumar, 2023). However, introducing E-buses in Pakistani cities encounters several challenges, including infrastructural limitations, financial constraints, regulatory hurdles, and public awareness (UNFCC, 2022). Analysing these obstacles and assessing the current advancements can pave the way for a successful shift to E-buses in Pakistan's urban environments.

## 1.3. Research Questions

- a) Has Pakistan successfully established an ecosystem for e-bus operations?
- b) What are the key challenges to the adoption of e-bus technology in Pakistan, and which policy measures are needed to ensure its smooth implementation?

## 1.4. Significance of the Study

The significance of adopting electric buses (e-buses) in Pakistan lies in their potential to address the country's multiple critical challenges, particularly in urban air quality, public health, and the high economic costs associated with fossil fuel dependency. Pakistan is one of the most polluted countries in the world, with major urban centres like Lahore and Karachi suffering from high levels of air pollution mainly due to vehicular emissions. In this context, transitioning from diesel-powered public transport systems to electric buses offers an opportunity to reduce urban air pollution significantly and contribute

to global efforts to mitigate climate change.

Moreover, adopting e-buses aligns with Pakistan's broader commitment to international climate agreements, such as the Paris Agreement, by helping the country lower its carbon footprint. The National Electric Vehicle Policy (NEVP), introduced in 2019, sets a target for 30% of all vehicles, including buses, to be electrified by 2030. This policy emphasises environmental sustainability and energy security, the creation of green jobs, and reducing the country's reliance on imported fossil fuels. Thus, the shift to e-buses holds both environmental and economic significance for Pakistan.

### 1.5. Scope of the Study

This study focuses on the financial feasibility and technical challenges of implementing electric buses in Lahore as a pilot case for national adoption. It provides an in-depth analysis of the infrastructure requirements, cost sustainability, and operational barriers critical to transitioning to e-buses. Additionally, the study evaluates the potential environmental benefits, such as reducing greenhouse gas emissions and improving air quality, and highlights how these gains align with Pakistan's National Electric Vehicle Policy (NEVP). While centered on Lahore, the findings are intended to guide similar initiatives in other urban centres across Pakistan facing comparable environmental and public transport challenges.

### 1.6. Literature Review

The adoption of electric buses has gained significant momentum globally, driven by the urgent need to address air pollution, reduce greenhouse gas emissions, and transition to sustainable energy sources in public transport. Several countries, including China, India, and Brazil, have been at the forefront of this transition. This literature review examines the critical global trends, challenges, and best practices in electric bus adoption, focusing on lessons that can be applied to the Pakistani context.

China is the world leader in e-bus adoption, with cities like Shenzhen operating more than 16,000 electric buses (World Bank Group, 2021). China's success can be attributed to strong government policies, massive investments in charging infrastructure, and local manufacturing capabilities (Bloomberg, 2023). Similarly, European cities such as Amsterdam and Paris have advanced electric bus networks supported by comprehensive policies and renewable energy sources for powering the buses (IEA, 2024). In India, the government has implemented the Faster Adoption and Manufacturing of Electric Vehicles (FAME) program, which provides subsidies and incentives for the procurement of electric buses. Cities like Delhi and Pune have successfully rolled out e-bus fleets, mainly benefiting from this central government support (Kumar, 2023; Kohli, 2024) India's experience highlights the importance of central government intervention, local manufacturing, and public-private



partnerships in reducing the financial burden of adopting electric buses.

Despite the clear benefits, the transition to electric buses is challenging. The high initial capital expenditure (CAPEX) required to purchase electric buses and establish charging infrastructure remains a significant barrier (Avenali, 2024). Additionally, the lack of local manufacturing capacity in many developing countries results in a reliance on expensive imports, further increasing costs (Tarei, 2021). The infrastructure for charging electric buses is another major challenge. Most cities, particularly in developing countries, lack a robust charging station network (Kumar, 2023).

Furthermore, the need for continuous energy supply and reliable grid infrastructure is critical to the success of electric buses. This challenge is particularly pronounced in countries like Pakistan, which face frequent energy shortages (Asghar, 2021). Lessons from India, China, and other developing countries are invaluable for Pakistan. India's focus on building local manufacturing capabilities and its subsidy-driven FAME program provides a blueprint for reducing the cost of electric buses and encouraging wider adoption (Kohli, 2024). Similarly, China's investment in charging infrastructure and renewable energy sources highlights the importance of integrating electric buses into a sustainable energy ecosystem (Jain, 2022).

Pakistan must prioritize public-private partnerships and seek international financial assistance to overcome the economic and infrastructural barriers associated with electric bus adoption. Recent studies indicate that transitioning to battery electric buses (BEBs) in urban centers can significantly reduce the total cost of ownership by approximately 30% over a bus's lifecycle, despite the high initial investment in charging infrastructure and vehicles. Public-private collaborations, combined with international donor support, can bridge the financial gaps, enabling Pakistan to capitalize on the environmental and economic benefits of electric buses (Asghar, 2021).

## 1.7. Research Methodology

This study employs a mixed-methods approach to evaluate the feasibility and potential benefits of introducing electric buses (e-buses) in Lahore, Pakistan. By integrating qualitative insights with quantitative analysis, the research provides a comprehensive understanding of the challenges and opportunities associated with this transition, while offering actionable recommendations tailored to the local context.

The qualitative component involves a comparative case study methodology, focusing on best practices from countries such as China, India, and Bangladesh. Through a systematic review of policy documents, academic literature, and case-specific reports, the study examines how these nations successfully transitioned to electric buses. Key strategies such as robust government policies, local manufacturing capabilities, and public-private partnerships are

analyzed to extract transferable lessons. These insights contextualize Pakistan's efforts within the global movement for sustainable urban transportation, offering frameworks that could inform the adoption of e-buses in Lahore.

A significant part of the research involves analyzing the 'Feasibility Study for Lahore EV Buses' conducted by the Punjab Transport Company (PTC). This feasibility study provides location-specific data on potential routes, operational considerations, cost estimates, and infrastructure requirements. This study critically evaluates these findings against global benchmarks and local policy frameworks. A meta-analytical framework is employed to validate and synthesize data by triangulating the feasibility study's assumptions with insights from comparative case studies and stakeholder responses. This approach ensures a rigorous cross-validation of findings, enhancing the robustness of recommendations for Lahore's e-bus adoption.

Primary data is incorporated through a structured questionnaire designed for key stakeholders, including the Secretary of Transport & Mass-transit Department and the Director of the Transport Planning Unit. The questionnaire addresses pre-pilot planning areas such as policy alignment, financial sustainability, infrastructure readiness, and potential operational challenges. These responses complement the secondary data, providing a nuanced understanding of stakeholder perspectives.

The quantitative component involves a cost-benefit analysis based on data from the PTC feasibility study. This analysis evaluates the total cost of ownership (TCO) by comparing the capital expenditure (CAPEX), operational expenditure (OPEX), and long-term savings of e-buses against traditional diesel buses. Environmental data, such as emission levels and air quality indices, are also analyzed to estimate reductions in greenhouse gas emissions and particulate matter. These findings emphasize the environmental and public health benefits of transitioning to e-buses in Lahore.

By combining global case studies, local policy analysis, the findings of the PTC feasibility study, and primary insights from stakeholders, the research adopts a meta-analytical approach to validate and synthesize its findings. This methodology provides a comprehensive and evidence-based understanding of the feasibility and benefits of electric buses in Lahore. Through this framework, the study aims to offer actionable, context-specific recommendations for addressing the financial, infrastructural, and regulatory challenges that must be navigated to transition successfully toward sustainable urban mobility in Lahore.

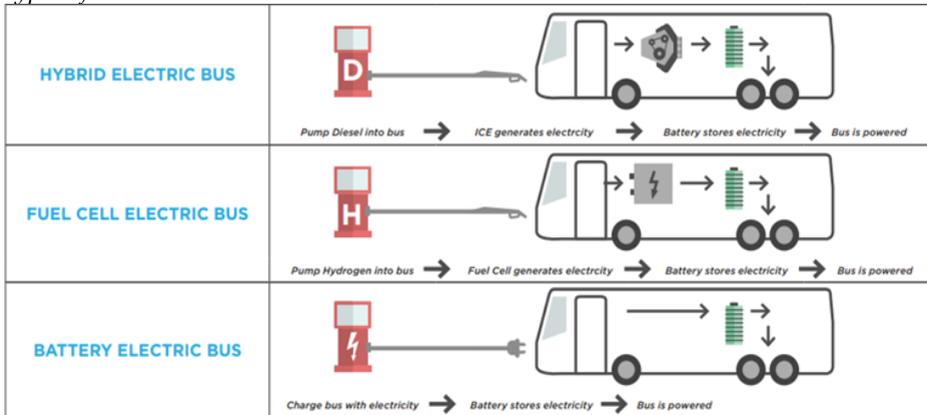


## 2. Situational Analysis of E-Bus Adoption in Pakistan

The world is shifting toward electric vehicles (EVs) as a critical response to the growing concerns about the environment, sustainability, and public health emanating from fossil fuel dependency. Electric buses are key to this paradigm shift as they offer a cleaner and sustainable alternative to legacy fossil-fuel transportation. Countries like Pakistan, which are at a greater risk of urban environmental pollution and dependence on imported fuel, find the adoption of electric buses to be an environmental and economic necessity.

**Figure 2**

*Types of Electric Buses*



Source: (Grütter, 2019)

Electric buses offer a cost-effective solution in dealing with environmental sustainability, urban air pollution, reduction in greenhouse gas emissions, and modernizing public transportation globally. Electric buses are categorized into three major types: a) hybrid, b) fuel cell, and c) battery electric types. These buses are powered by electric motors, with battery electric buses (BEBs) being the most common, using onboard batteries to store and supply energy. Other technologies include hybrid electric buses (HEBs) and fuel-cell electric buses, which generate power through hydrogen-based chemical reactions (Grütter, 2019).

The ZEBTA report offers insights into the differences between various types of buses—diesel, hybrid, fuel cell electric, and battery electric—across several metrics, including purchase costs, fuel/energy costs, maintenance, and total cost per mile. Notably, battery electric buses (BEBs) offer the lowest total cost per mile, making them an economically viable option in the long term compared to diesel buses, traditionally relied upon in countries like Pakistan. According to the ZEBTA report, while battery electric buses have a higher purchase cost at \$938,184, their fuel cost per mile is significantly lower at \$0.46,

compared to \$1.01 for diesel buses. This indicates that the initial investment in BEBs can lead to substantial savings over the vehicle's lifecycle, particularly in fuel and maintenance (CTE, 2022).

**Table 1**

*Comparative Costs of Bus Types*

Bus Type	Purchase Cost (USD)	Energy/ Fuel Cost	Maintenance Cost	Total Cost
		Per Mile, USD		
Diesel Bus	\$488,247	\$1.01	\$1.28	\$2.29
Hybrid Electric Bus (HEB)	\$699,060	\$0.74	\$2.37	\$3.11
Fuel Cell Electric Bus (FCEB)	\$1,156,044	\$1.19	\$1.33	\$2.52
Battery Electric Bus (BEB)	\$938,184	\$0.46	\$1.15	\$1.61
Legacy Fuel Cell (FC)	\$1,232,095	\$1.69	\$2.46	\$4.15

*Source:* (CTE, 2022)

## 2.1. Government Policies and Initiatives

Pakistan introduced National Electric Vehicle Policy (NEVP) in 2019 as broader policy measure to address environmental and economic challenges by modernizing public transport. The NEVP sets a target to electrify 30% of all vehicles in Pakistan by 2030, including buses, as part of the country's commitments to reduce its carbon footprint and address air pollution in major urban centres, Figure 2 elaborates on the challenge of rising PM 2.5 levels in Pakistan (Earth, 2024) which are the major contributors to air pollution. (Government of Pakistan, 2019). The policy focuses on environmental sustainability, promoting energy security, and creating green jobs, aligning with global climate agreements such as the Paris Agreement (UNFCCC, 2022).

One of the NEVP's critical features was its fiscal incentives to encourage the adoption of electric vehicles (EVs) across the board by reducing import duties on electric batteries, charging equipment and slashing General Sales Tax (GST) on EVs to 1% (Uddin, 2020). These tax reliefs were designed to reduce the initial costs associated with EVs, particularly electric buses, and stimulate investment in the production and infrastructure needed for their adoption.

However, the Finance Bill 2024-25 introduced adjustments to these policies, particularly concerning importing luxury EVs. Removing duty exemptions for vehicles priced above \$50,000 reflects a shift in the government's focus towards



promoting local manufacturing rather than supporting the import of high-end electric cars.

## 2.2. Federal and Provincial Coordination

Punjab and Sindh are in the process of implementing pilot projects of electric busses in public transport, focusing on eco-friendly alternatives in urban cities. Punjab is set to expand its pilot from Lahore to Rawalpindi and Faisalabad. Sindh government has initiated a pilot targeting Karachi's growing public transport system. The success of these pilot programs rests on effective coordination with federal government, which poses a significant threat due to regulatory changes in policies (Uddin, 2020).

The shift to e-buses rests on the key requirement of development of robust network of charging infrastructure for large-scale adoption. National Electric Vehicle Policy 2019 underscores the importance of this critical requirement and stipulates a plan for development of fast-charging stations across Pakistan. However the pace of implementation has lagged because of financial and logistical constraints.

## 2.3. Regulatory and Financial Support

Public-private partnership offers a viable solution to bridge the infrastructure and financing gaps, the government has underscored its importance by encouraging private sector for investment. The policy is aimed at accelerating this transition to environmentally friendly public transport system by outlining mechanisms for long-term financing and regulatory adjustments to support adoption of electric busses as an economically viable option for transport operators in the public sector (Uddin, 2020).

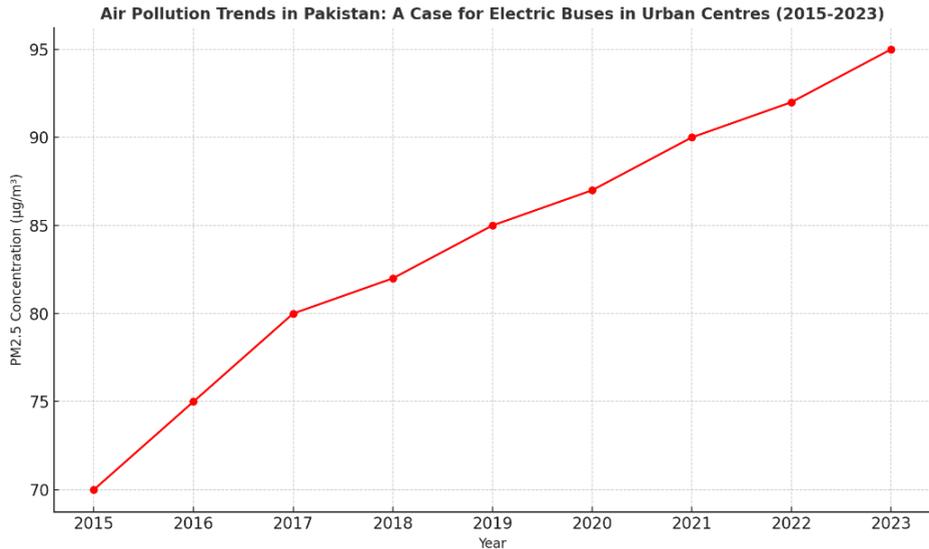
The revisions in the Finance Bill 2024-25 illustrate a pragmatic shift in policy. They focus on fostering local capacity while maintaining a commitment to reducing Pakistan's dependence on fossil fuels and meeting its Nationally Determined Contributions (NDCs) under global climate agreements. The overall policy framework, while still evolving, signals Pakistan's intention to leverage both fiscal incentives and regulatory support to promote electric busses' adoption and sustainably enhance urban mobility (KPMG, 2024).

## 2.4. Pilot Projects of E-Buses in Pakistan

As discussed earlier, there are three major initiatives across Pakistan focusing on integrating electric buses into public transport system in Islamabad, Karachi and Lahore. However, the progress has been slow owing to financial constraints, weak economic situation and infrastructure and policy gaps that needs to be addressed. The following section outlines an overview of the e-bus adoption in Pakistan by critically examining the government policies and the pilot projects in various cities.

Figure 3

*Air Pollution Trends in Pakistan*



Source: (Earth Org., 2024)

Pakistan's urban centers rank among the most polluted in the world due to the significant contribution of vehicular emissions to atmospheric pollution. Lahore has now transformed into a city where the levels of particulate matter (PM 2.5) are consistently dangerous, posing a severe risk to the public at large.

The public transport system comprises of diesel buses predominantly, which contributes to the worsening air quality and adds financial strain at a cash-strapped economy. Furthermore, Pakistan's vulnerability is further exacerbated by its reliance on imported fossil fuel.

Electric buses have emerged as an essential driver for mitigating urban pollution, their efficiency and environmentally friendly operations makes them a viable option for countries aiming for greener future. Cities like Islamabad, Karachi and Lahore which are struggling with pollution and urban sprawl e-buses offer a sustainable solution. Electric buses do not produce tailpipe emission, which makes them environmentally friendly (Masood, 2024).

Additionally, the economic benefits of adopting e-buses are significant. While the initial capital investment in e-buses and their associated infrastructure (such as charging stations) is high, the long-term savings on fuel and maintenance costs can offset these expenses. Electric buses require fewer parts than traditional combustion engines, leading to lower maintenance costs over their lifespan (PTC, 2023). As fuel prices continue to rise globally, the cost-effectiveness of e-buses becomes even more apparent (Think Transport, 2024).



At the provincial level, both Punjab and Sindh are leading the way in implementing the federal government's policy framework. In Lahore, the Punjab Mass-transit Authority (PMA) has taken proactive steps to introduce electric buses to modernise the city's public transport system. Similarly, with its People's Bus Service, Karachi is laying the groundwork for a sustainable transport network that includes electric buses on major routes. These provincial initiatives are crucial for ensuring that the NEVP's goals are translated into practical actions on the ground (PTC, 2023; Think Transport, 2024).

However, while the policy framework is in place, significant challenges remain in the implementation phase. The development of charging infrastructure has been slow, and there is still a lack of coherence between federal and provincial policies regarding subsidies and operational guidelines.

However, frequent policy changes can impact this adoption, for example in the current fiscal year 2024-25 government of Pakistan removed the duty exemptions for EVs valued more than \$50,000. This is further compounded by the fact the local auto-manufacturing industry lags in shifting towards electric vehicle technology and reliant on imports, which adds to the cost and slows the pace of e-bus adoption (Asghar, 2021; Uddin, 2020).

In July 2024, Capital Development Authority (CDA), introduced 30 electric buses in Islamabad, making it the first city in Pakistan to deploy EV buses in public sector transport system. These buses cover two routes, which are surrounded by densely populated areas and major commuter corridors (Masood, 2024).

These routes were chosen strategically to maximise ridership and demonstrate the benefits of electric buses in reducing traffic congestion and pollution.

Karachi's People's Bus Service has also integrated electric buses into its fleet, marking a significant step forward for sustainable transport in the country's largest city. The service operates on routes connecting critical industrial and commercial hubs, offering commuters a reliable and eco-friendly alternative to conventional buses. With Karachi's notorious traffic congestion and air quality issues, introducing e-buses is seen as a critical intervention to reduce pollution and commuting times. The Sindh government has committed to expanding the electric bus fleet over the next few years, with a target of 360 electric buses by 2025 (Think Transport, 2024).

A key challenge in scaling e-bus adoption is the high initial capital expenditure (CAPEX) required for purchasing electric buses and setting up the necessary infrastructure. While e-buses have lower operational costs than traditional diesel buses, the initial acquisition cost remains a significant barrier. In Pakistan, this is compounded by the lack of local manufacturing capacity for EV components, which necessitates importing expensive technologies and

parts (PTC, 2023).

Empirical data from the pilot projects in Islamabad, Lahore, and Karachi show that operational expenditure (OPEX) for e-buses is significantly lower than for traditional buses. For example, in Lahore, the Feasibility Study for Lahore EV Buses (2023) projected that e-buses would have an OPEX of approximately PKR 229.77 per kilometre compared to traditional diesel buses, which have significantly higher fuel and maintenance costs (PTC, 2023).

However, the financial viability of these projects is still heavily reliant on government subsidies and international economic assistance. Public-private partnerships (PPPs) have been instrumental in financing the pilot projects, with global organisations like the Asian Development Bank (ADB) and the World Bank providing critical support in funding and technical expertise. These partnerships are essential for bridging the financial gap and ensuring Pakistan can meet its electrification targets by 2030 (Think Transport, 2024).

## 2.5. Partnerships and Investments

Public-private partnerships (PPPs) have played a critical role in e-bus adoption in Pakistan. These partnerships have facilitated the pooling of resources, technical expertise, and financing needed for large-scale projects. The government has actively sought collaborations with the private sector to introduce e-buses and develop the required infrastructure. For example, the partnership between Karachi's government and Chinese firms like Build Your Dreams (BYD) and China Machinery Engineering Corporation highlights the role of international partnerships in promoting electric transport (The Express Tribune, 2022).

Additionally, Pakistan has attracted investment from financial institutions and international donors to support its e-bus sector. Institutions like the Asian Development Bank (ADB) and the World Bank have provided financial assistance and technical expertise to bolster the adoption of electric buses in urban areas. These investments are essential for overcoming the economic barriers associated with the high initial cost of e-buses and the development of charging infrastructure (Grütter, 2019). Such partnerships and investments are expected further to drive the expansion of electric bus networks in Pakistan and contribute to achieving the country's sustainability goals.

## 2.6. Case Study: Lahore's Electric Bus Pilot Project

In Lahore, a more comprehensive feasibility study was conducted to identify the most viable routes for electric bus deployment. The study, undertaken by the Punjab Transport Company (PTC), focused on critical high-demand areas and integrated public transport hubs. The report projected significant savings in operational costs over the long term despite the higher initial capital expenditure required to purchase and maintain electric buses. Lahore's electric



bus project is designed to be scalable, with plans to expand the fleet based on the success of the initial phase (PTC, 2023).

### 2.6.1. Identification and Selection of Potential Routes

The piloting of electric busses in Lahore aimed at identifying the most feasible routes for piloting electric buses, assessment of key barriers to e-bus adoption ranging from charging infrastructure requirements, identification of depots, operational plan and integration of these e-buses into Lahore's mass transit system.

The study carried out a comprehensive review of suitable transport routes, leveraging insights from previous studies like Integrated Bus Operation Study (IBO-2016), Punjab Mass-transit Authority (PMA) and Punjab Transport Company, who provided essential data on public transport ridership in Lahore.

The study involved multiple site visits to Lahore to understand the city's existing transport system, including its Metro Bus and Orange Line Train systems. Surveys were conducted on public transport routes to map current vehicle occupancy and ridership levels. The report used this data to recommend five potential routes for introducing electric buses. These routes were selected based on public transport demand, infrastructure availability, and operational feasibility. Lahore's public transport system includes a mix of informal (Qingqis, wagons) and formal (Metro buses, Speedo buses, Orange Line) services. The consultant ensured that the proposed routes do not overlap significantly with existing high-capacity transit lines, including the Metro Bus and Orange Line Train. Notably, some routes are intended to serve as feeder lines for the Orange Line, given that no dedicated feeder service exists currently (Government of Punjab, 2023).

The consultant also mapped existing routes through primary surveys, analysing public transport gaps and identifying potential corridors to enhance network coverage in Lahore. Old data from the Lahore Transport Company (LTC) was reviewed, including ridership statistics and route alignments, which helped shortlist viable routes for electric bus operations. In coordination with the PTC, the consultant ensured that existing routes running parallel to the proposed electric bus routes would either be closed or rerouted to minimise direct competition, particularly with Speedo buses. This iterative process further refined potential routes using primary data collection to ascertain demand along the corridors (Government of Punjab, 2023).

However, the city faces significant traffic congestion, air pollution, and reliance on diesel buses. Diesel buses contribute significantly to greenhouse gas emissions and urban air pollution. The study highlighted that improving air quality is a critical driver for introducing electric buses.

Given Lahore's environmental goals under SMOG Action plan and the need for

lower emissions, Battery Electric Buses (BEBs) were identified as the most suitable option due to their zero-emission potential and lower operational costs. Following a detailed analysis of existing transport patterns and operational feasibility, five potential routes were shortlisted for the pilot project. These routes as provided in Table 2, were assessed individually based on operational plans, demand estimations, and financial viability. (PTC,2023).

**Table 2**

*Proposed Public Transport Routes in Lahore*

Depot Location	Route ID	Route Alignment	Route Length	Fleet Requirement	Headway (min)	Dead Mileage
Railway Station	Route 1	RA Bazar to Civil Secretariat:	12.8 Km	16	8	6.1 km
	Route 2	GBS to RA Bazar	14.6 Km	19	8	2.8 km
Kot Lakhpat Depot	Route 3	Railway Station to Green Town	26.0 Km	27	10	5.9 km
	Route 4	Railway Station to Abu Bakar Chowk	24.5 Km	26	10	1.3 km
Jinnah Terminal	Route 5	BRB to Jinnah Bus Terminal	35.75 Km	36	10	-

Source: (PTC, 2023)

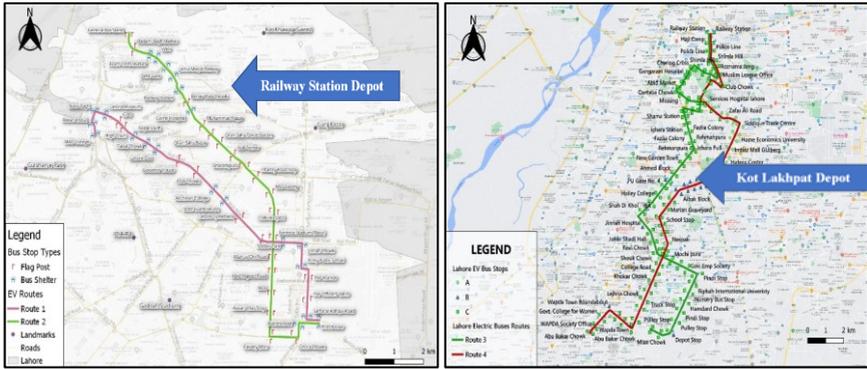
### 2.6.2. Scenario Development and Finalization of Routes

The consultant has proposed five critical routes for the electric bus pilot in Lahore, spanning a total distance of 115 km. These routes were designed to strategically serve high-demand areas, fill gaps in the current transport network, and reduce congestion along vital urban corridors.



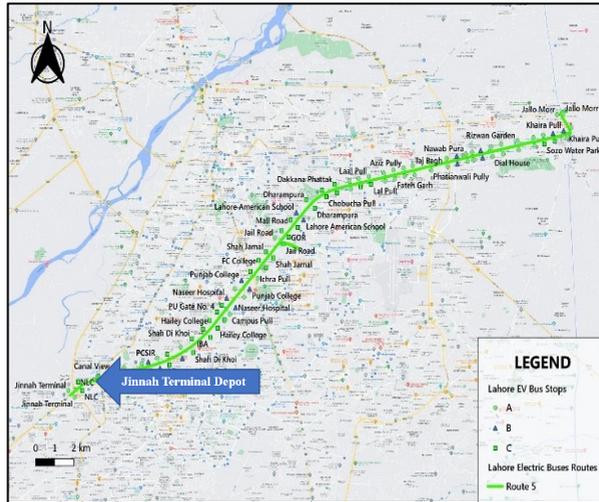
Figure 4

Proposed Routes for Lahore E-Bus Pilot and Bus Depots



Route 1 & 2 Railway Station Depot

Route 3 & 4 Kot Lakhpat Depot



Route 5 Jinnah Terminal Depot

Source: (PTC, 2023)

### 2.6.3. Charging Infrastructure and Depot Requirements

Most of the feasibility study focused on identifying the infrastructure requirements for charging electric buses. The report advocates for two main charging options: slow charging, which would take place overnight at depots, and fast charging, which could be used during operational hours for a quick energy boost.

Charging depots were identified for each proposed route, with

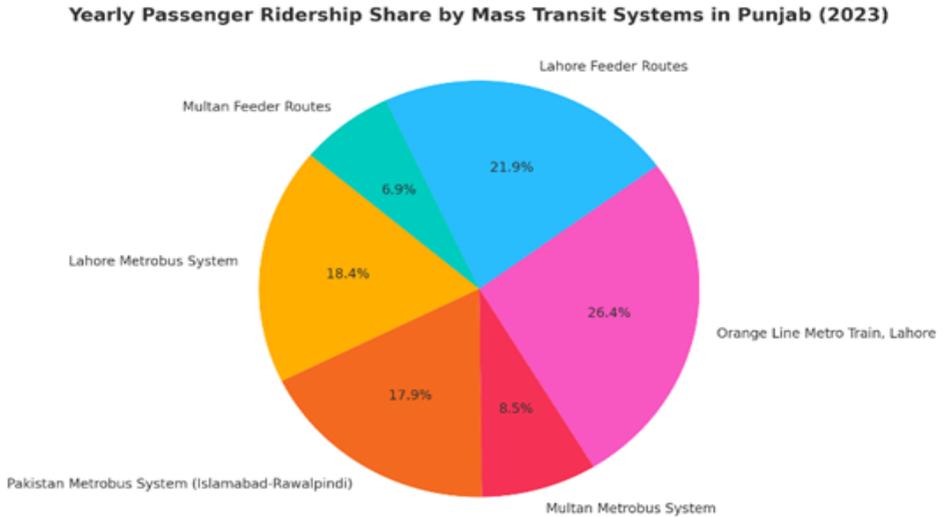
recommendations for size and layout. The report also highlighted the importance of integrating charging stations into Lahore's energy grid, considering factors like peak energy demand and cost-efficiency. The proposed routes and associated depot locations are illustrated in Figure 4.

#### 2.6.4. Financial Feasibility

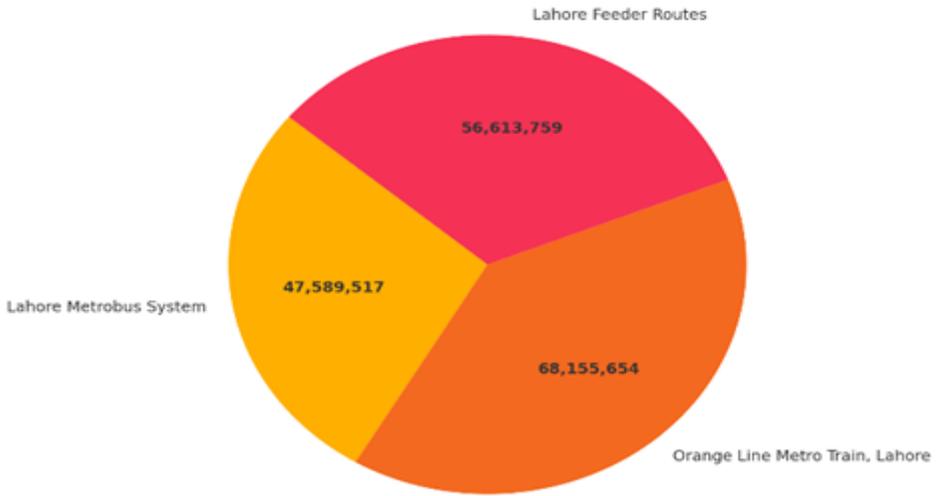
The financial analysis presented in the study commissioned by PTC shows that although the capital expenditure (CAPEX) for electric buses is high, the operational expenditure (OPEX) is significantly lower than that for diesel buses. Two fare slabs, FS-I and FS-II, were considered for revenue projections. In both cases, revenue generation was lower than the required subsidy, emphasising the need for government intervention and international financial support to sustain the project.

**Figure 5**

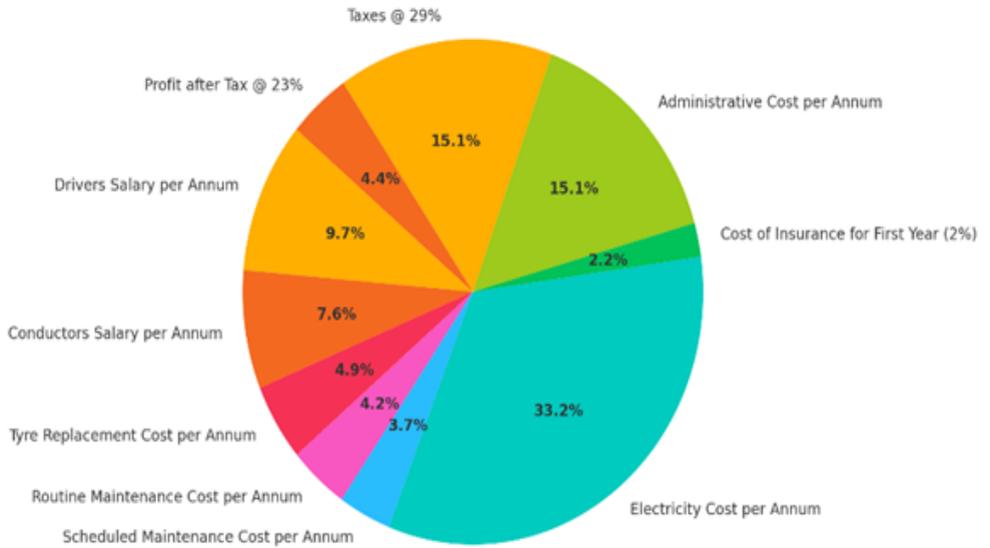
*Analysis of Passenger Ridership Share of Lahore and Route Parameters*



**Yearly Passenger Ridership Share in Lahore (2023)**

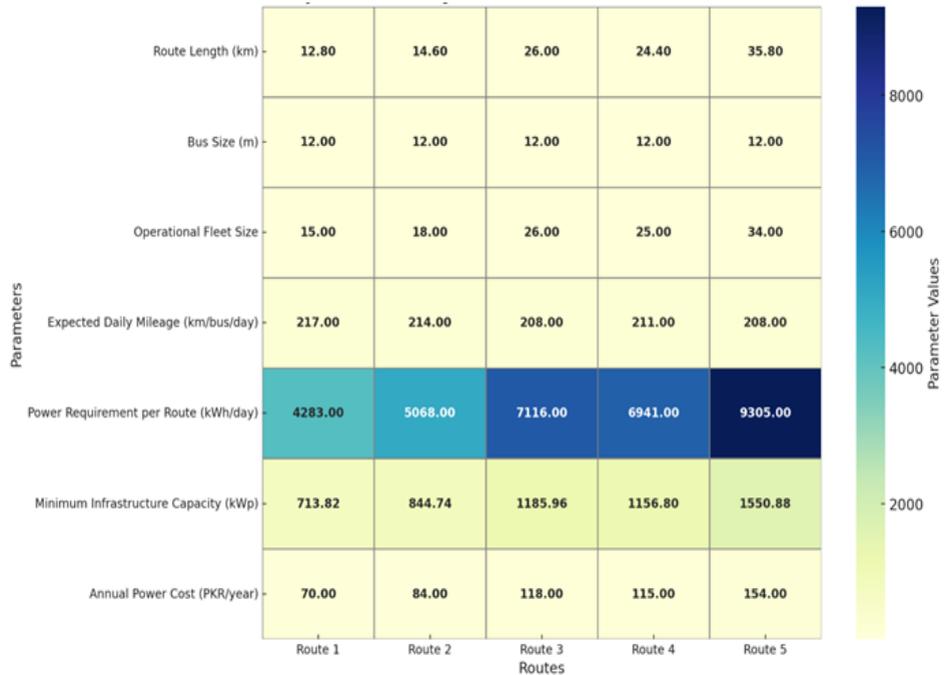


**Cost Distribution for E-Buses in Lahore**



Source: (PTC, 2023)

**Table 3**  
Comparative Analysis of Route Parameters



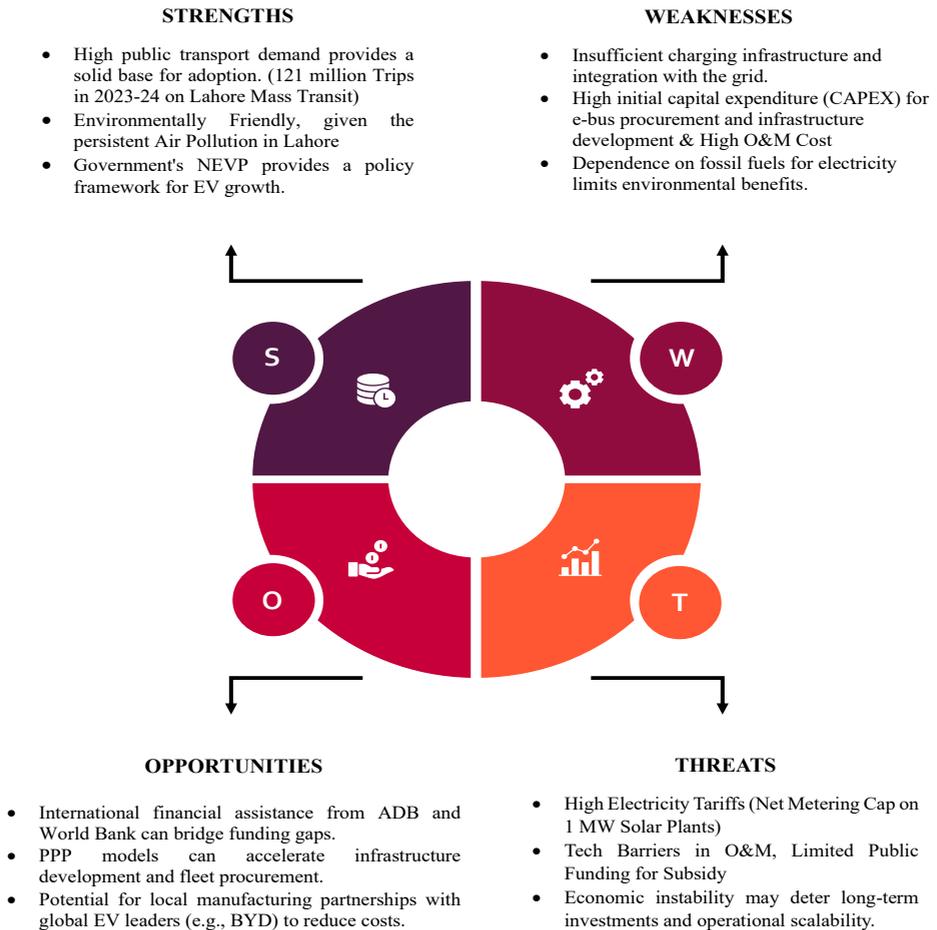
Source: (PTC, 2023)

The Lahore Electric Bus Pilot Project capitalizes on Punjab’s massive public transport demand—over 258 million riders in 2023, including 172 million in Lahore—by prioritizing high-demand corridors like the Orange Line Metro Train and Lahore Feeder Routes. Figure 5 highlights electricity and administrative expenses as the largest cost drivers, emphasizing the need for targeted subsidies and strategic financial planning. Comparative analysis of route parameters underscores the necessity of optimized infrastructure and energy allocations, aligning the project with Lahore’s sustainable transport and economic objectives.



**Figure 6**

*SWOT Analysis for Lahore's Electric Bus Adoption*



**2.6.5. Key Challenges**

The key challenges and opportunities were identified by employing SWOT analysis of the feasibility report on *“Piloting of Electric Busses in Lahore”* by Punjab Transport Company.

- a) **High Capital Costs:** Introduction of e-buses require high capital costs, including the costs of e-buses and infrastructure requirements etc.
- b) **Infrastructural Gaps:** The city lacks the necessary infrastructure for electric bus operations, including charging stations and depots.
- c) **Policy and Regulatory Support:** Coherent policies that provide

financial incentives, subsidies, and regulatory frameworks to support electric buses are needed.

In order to mitigate the key challenges identified, the study recommends introduction of e-buses in phases on the identified routes. It also highlights the importance of leveraging public-private partnership and multilateral support from institutions like Asian Development Bank to ensure financial viability.

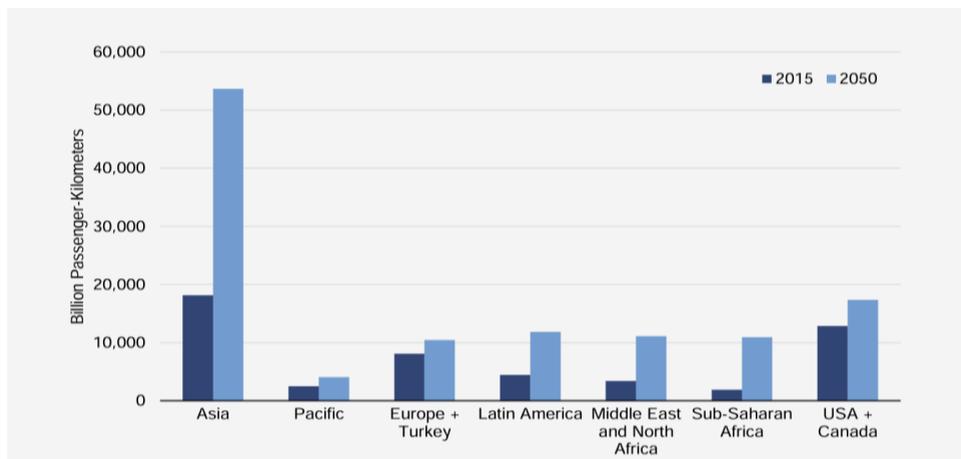
Given the current situation of air pollution and smog in Lahore, Punjab government has introduced an ambitious “Smog Action plan” focusing on reduction of air pollution by promoting sustainable transportation to achieve better air quality. In addition to this, upcoming programs like Clean Air Program, financed by World Bank will improve the integration of e-buses in Punjab.

### 3. Comparative Analysis With Region

The passenger transport demand in Asia (OECD, 2023) is expected to grow exponentially, which highlights the importance of mainstreaming greener technologies for public sector transportation to meet the growing demand in a sustainable and environmentally friendly way. This section provides a comparative analysis of the current level of e-buses in key regional countries by identifying trends, barriers and lessons.

**Figure 7**

*Passenger Transport Demand (2015-2050)*



*Source: (OECD, 2023)*

#### 3.1. Regional Case Studies

The adoption of E-bus has gained traction in several developing countries that face similar socioeconomic and environmental constraints like Pakistan

including India and Bangladesh. Table 4 contains the meta-data resulting from a literature review of the regional practice of e-bus adoption in China, India, and Bangladesh based on factors in policies, infrastructures, manufacturing industries, and public transportation systems, though it should be noted that the cross-sectional analysis of this table assumes equal weights of each factor across the total score. Recognizing these trends and issues and understanding how they correspond to Pakistan's context is the focus of this meta-analysis to identify strategies to transfer and apply to enhance the electric bus diffusion in the country

- a) India has made remarkable strides in electric bus implementation under its Faster Adoption and Manufacturing of Hybrid and Electric Vehicles (FAME) program. The FAME II framework, supported by \$1.36 billion, keeps liberal subsidies & incentives for the adoption of e-buses. Cities like Delhi and Pune have already implemented e-bus services with help from central government, strong and favorable policies and public-Private partnerships. It has also addressed critical issues such as low first-entry expenses and infrastructure issues, and centralized manufacturing capacity, which has been instrumental in lowering procurement costs and acquiring technical experience (Jain, 2022; Kohli, 2024). Looking forward, plans for FAME III are to scale up the adoption even further, and specifically for deserving areas and missing infrastructure.
- b) Bangladesh, while at an earlier stage of adoption compared to India, is progressing by focusing on international collaborations with organisations such as the Asian Development Bank (ADB) to secure funding and technical expertise. Dhaka has initiated pilot projects to integrate electric buses into its public transport system, targeting the reduction of severe air pollution and congestion. The success of these projects has been attributed to international cooperation in technology transfer and capacity building, which reduces dependency on costly imported technology and builds local operational expertise (Grütter, 2019). Although challenges persist, Bangladesh's focus on securing global partnerships demonstrates a promising pathway for scaling sustainable urban transport.
- c) China has emerged as the global leader in e-bus adoption, operating over 400,000 electric buses, with Shenzhen serving as a flagship example. This remarkable achievement is underpinned by robust government policies, extensive subsidies, and significant investments in charging infrastructure. Additionally, the dominance of local manufacturers like BYD and Yutong, which have pioneered innovations in battery and vehicle technology, has ensured China's leadership in the sector. The integration of renewable energy into the charging network has further enhanced the environmental benefits of this large-scale adoption (Bloomberg, 2023; Kohli, 2024).
- d) Meanwhile, European countries like Netherlands and Luxembourg have

also demonstrated significant advancements, driven by comprehensive policies promoting sustainable urban transport, with national e-bus fleets of 81% and 51% respectively. These cities have integrated renewable energy into their e-bus operations, ensuring their fleets are both efficient and environmentally sustainable. Policy incentives, funding mechanisms, and the emphasis on renewable energy sources have allowed these cities to achieve scalability and maintain long-term sustainability in their e-bus networks (Kohli, 2024; IEA, 2024).

These regional case studies, coupled with insights from the meta-analysis in Table 4, illustrate critical strategies that Pakistan can adopt to overcome its own challenges in scaling e-bus adoption. India's focus on public-private partnerships and local manufacturing, Bangladesh's reliance on international funding and capacity-building collaborations, and China's investment in infrastructure and local production all serve as models for Pakistan to develop its own comprehensive framework. Learning from these examples, Pakistan can implement targeted policies, encourage international partnerships, and invest in local manufacturing to enable a successful transition to sustainable urban transport.

## **4. Challenges In Introducing E-Buses In Pakistan**

### **4.1. Infrastructure and Technology Constraints**

The use of e-buses in the Pakistan has several issues, one of its major issues is that there is no provision of charging infrastructure. For these buses to work, a system backed by multiple points for recharging is required. However, the charging infrastructure in Pakistan is scarce, and sparsely distributed for private cars and has a limited capacity to support mass e-bus operations in the country (Asghar, 2021). Also, energy crises and lack of sustainable resources in Pakistan further exacerbates the limitations; besides, most of the resources used by e-vehicles in Pakistan are non-renewable. In this situation, e-buses lose their environmental advantage if they use electricity from coal or other conventional energy resources (Asghar, 2021). Another technological constraint is the limited ability to carry out repair and maintenance of electric buses since there are limited suppliers of aftermarket parts for green technologies locally. E-buses need specific maintenance given their battery-mix and electrical system and lack of skilled human resource and after sales service centers for e-buses make it difficult for maintaining operational sustainability (Asghar, 2021; Masood, 2024). Therefore, these challenges impact the reliability and feasibility of e-buses operations for public transport.

### **4.2. Financial and Economic Barriers**



Another major challenge for e-bus adoption is the high capex cost at the initial stage. The electric buses are more expensive than conventional diesel or CNG buses, both at purchase and operations stage necessitated by costly charging infrastructure (Kumar, 2023; Sadrani, 2024). The risk of such an investment can be costly for the local governments particularly where such entities are challenged financially and have many demands for their limited resources. The financial risk associated with such an investment can be a disincentive for local governments and transport authorities, which often face budget constraints and competing priorities (Grütter, 2019). A cost benefit analysis between e-buses and a traditional diesel buses demonstrate that even if e-buses are a good long-term investment as they do not require a lot of fuel and require less maintenance, the monetary outlay in this case remains a pitfall for struggling local governments

### 4.3. Policy and Regulatory Gaps

The third issue is the absence of uniform policy for developing urban transport system across the provinces. Whereas the federal government has recently announced the National Electric Vehicle Policy (NEVP), its execution is mostly a provincialized subject and as such lacks synergy (Aslam, 2020). For instance, Karachi and Lahore have demonstrated some readiness in pilot phase, but other important cities lag behind due to varying priorities of provincial governments and their regulatory environments.

In addition, there are no medium to long-term overall strategic orientations of sustainable urban transport systems with the integration of e-buses as their focal-driver. Without such plans, attempts to introduce e-buses will remain random and will not address the problem of mobility and environmental sustainability in large cities. Practical difficulties are also experienced in incorporating e-buses within the current public transport systems that are developed with traditional vehicles in mind (Masood, 2024). There current regulatory framework needs to be updated so that it can support the scaling-up of e-buses, including safety standards, licensing requirements, and incentives for operators.

According to Sadrani et al. (2024) high purchasing cost of e-buses, inadequate charging facilities, and maintenance cost are the major challenges globally. Other issues include, but not limited to, financing constraints and grid reliability in developing countries such as Pakistan hence the call for Africa appropriateness in the implementation of e-buses.

### 4.4. Social and Cultural Barriers

Another reason for slow implementation of e-buses is its restrictions by social and cultural factors in Pakistan. An idiomatic opinion of electric transport is not formed yet and many passengers have certain doubts regarding the efficiency and durability of e-buses compared to ordinary Diesel and CNG

buses (Aslam, 2020). To have such skepticism will slow down the rate at which users accept the e-bus services, especially when they face operational problems like breakdown or delays.

Also, opposition from transport unions and diesel buses owners, who argue that the use of electric buses to serve their interest may lead to their job loss. Such groups usually have deep political power influence, and may frustrate attempts at changing from using fossil-fuel intensive transportations. People also are generally unaware of the benefits of e-buses for the environment and health as well, which hinders the public support for governments' approaches to sustainable urban transport (Asghar, 2021). Without targeted public engagement these social and cultural barriers will impede the adoption of e-buses.

#### 4.5. What Can Pakistan Learn from Best International Practices?

Several important lessons can be drawn from regional best practices from which, Pakistan can learn, particularly in the field of technological innovation cost reduction strategies and policies. Thus, products likely to be adopted by users include those with some degree of local manufacturing capability taken from the experience of countries like India or China. India has been consistently trying to localize manufacturing facilities to cut procurement costs and develop local expertise, which has contributed to the sustainability of e-buses into the long haul (Jain, 2022). Pakistan can also follow the same route by incentivizing local companies, for manufacturing, by partnering with the global players to much needed technology capability to mainstream EV ecosystem.

However, there is potential to improve policies in Pakistan to drive the reduction of costs which would include subsidies for the procurement of e-bus, and other incentives to private players to adopt electric transport systems. This is evidenced by India's FAME initiative that shows that with strategic and central government incentives, the number of electric buses on the road can be boosted (Kohli, 2024). The same could be emulated in Pakistan's policy structures whereby the exemptions on taxes of imported electric vehicles, promotions of local manufacturers of e-buses, and grants to establish charging stations could mainstream EV transition.

In term of financing, it requires cooperation with the international organizations and the financial institutions. In Bangladesh's case, overseas financing from the Asian Development Bank (ADB) is one of the ways that financial needs can be filled while developing networks of e-bus systems in developing nations (Grütter, 2019). Pakistan can capitalize on financing these initiatives through ADB and the World Bank, and also seek assistance from China being the global leader in e-mobility.

Finally, Pakistan can learn the importance of integrated policy and incentive



frameworks from global leaders like China and Europe. The Chinese government's proactive stance on providing subsidies, establishing a robust charging infrastructure, and ensuring the use of renewable energy in powering electric buses has been critical to its success (Bloomberg, 2023). Similarly, European countries emphasise using clean energy sources, which maximises the environmental benefits of electric buses. Pakistan's transition to e-buses should be part of a broader strategy that includes incentives for renewable energy development, ensuring that clean energy rather than fossil fuels power electric buses.

## **5. Conclusion**

The global push toward electric vehicles (EVs), particularly in public transport, is essential for addressing environmental degradation, reducing fossil fuel dependency, and improving public health. In Pakistan, where cities face severe air pollution and volatile fuel costs, adopting electric buses (e-buses) is a critical step forward. Through the National Electric Vehicle Policy (NEVP) and provincial initiatives in Lahore and Karachi, the government has begun laying the groundwork for integrating e-buses into urban transport. However, several challenges remain despite their benefits, including lower emissions, reduced operational costs, and cleaner environments.

The Lahore Electric Bus Pilot Project underscores the complexity of implementing e-buses. The feasibility study by the Punjab Transport Company (PTC) highlights operational savings and environmental benefits, yet significant hurdles persist. High capital expenditure (CAPEX), insufficient charging infrastructure, and limited operator expertise are key barriers, compounded by inconsistent federal and provincial policies. The pilot project will launch with 27 e-buses, while 248 additional buses are being financed through the upcoming Clean Air Program funded by the World Bank. However, Lahore's estimated requirement of 1,500 buses highlights the scale of resources still needed to meet urban transit demands. Addressing this gap requires enhanced coordination, sustained international funding, and robust infrastructure development.

Lessons from countries like India, China, and Bangladesh provide valuable strategies, including promoting local manufacturing, reducing costs, and leveraging international financial support. Pakistan must prioritize these areas to achieve long-term sustainability and affordability for its e-bus program.

In conclusion, while Pakistan's transition to e-buses is in its early stages, policy initiatives and pilot projects provide a strong foundation. Successful implementation depends on addressing key infrastructural and financial gaps while fostering local capacity and technical expertise. Public-private partnerships (PPPs), federal-provincial alignment, and international collaborations are critical for bridging financial gaps and meeting

infrastructure demands. If these efforts are effectively coordinated, Pakistan can position itself as a regional leader in sustainable urban transport, with significant environmental and economic benefits for its urban centers.

With Pakistan in the process of transformation from fossil fuel dependent transport system the transition to electric buses (e-buses) is also a progressive shift towards sustainable urban transport. However, successful implementation requires addressing critical gaps in financing, infrastructure, and capacity building. Below are three key recommendations for moving forward. The following three strategies are proposed here as a way forward.

- a) **Develop Comprehensive Charging Infrastructure with Renewable Energy Integration:** The lack of adequate charging infrastructure remains one of the most significant barriers to scaling e-bus adoption. Interviews emphasize the urgent need for a phased approach to infrastructure development, starting with high-priority routes and depots identified in Lahore's feasibility studies. A robust network of strategically located charging stations must align with bus depots, key transport hubs, and heavily used corridors. Additionally, to address concerns about reliance on fossil fuel-generated electricity, the government must integrate renewable energy sources such as solar-powered charging units into the infrastructure. International support through programs like the Clean Air Program, funded by the World Bank, can play a pivotal role in financing these developments while ensuring energy efficiency and long-term cost reduction.
- b) **Strengthen Public-Private Partnerships (PPPs) for Financing and Operations:** The high capital expenditure (CAPEX) for e-buses and infrastructure requires innovative financial solutions. Public-private partnerships (PPPs) can bridge this gap by leveraging private-sector expertise and investments while providing government incentives and regulatory support. Building on international examples, such as India's FAME program, PPPs should focus on co-financing procurement, charging infrastructure, and maintenance. The Clean Air Program, funded by the World Bank, provides a critical opportunity to initiate large-scale financing and demonstrate a replicable model. Additionally, the engagement of development partners like the Asian Development Bank (ADB) can ensure sustainability and scale in these efforts.
- c) **Enhance Local Manufacturing, Research, and Skill Development:** To ensure cost efficiency and scalability, Pakistan must foster local manufacturing capabilities for electric buses and components. The interviews underscore the need for a long-term strategy to build domestic production capacity for batteries, motors, and e-bus systems. Partnering with international manufacturers for technology transfer and establishing a regional supply chain can significantly reduce costs. Furthermore,



targeted training programs for bus operators, technicians, and maintenance staff are essential to address the skill gaps highlighted in the primary data. Incentivizing local industries to collaborate with global leaders can accelerate self-sufficiency and economic growth while supporting e-bus adoption.

By focusing on these three key strategies —charging infrastructure, financing through PPPs, and local manufacturing—Pakistan can address the challenges identified and lay the foundation for a sustainable transition to electric buses. Implementing these strategies will not only improve air quality and reduce congestion in cities like Lahore but also set a benchmark for urban transport modernization across the country.

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**Annexure: A**

Annexure A: Comparative Analysis of Global Practices in EV Adoption

Category	China	India	Bangladesh	Evidence
Policy Support	Strong government policies with subsidies, tax exemptions, and local manufacturing incentives. Additional target for 100% electrified public fleets by 2035.	FAME II scheme with \$1.36 billion allocation; supports EV subsidies for buses, two-wheelers, and infrastructure development. Plans for FAME III are in progress.	Limited subsidies; focus on international funding (e.g., ADB) for pilot projects and technology transfer. Exploring a roadmap to cut transport emissions.	(Bloomberg, 2023; Jain, 2022); (Grütter, 2019) (Kohli, 2024)
Infrastructure	Comprehensive charging network supported by renewable energy integration, bolstered by government investment.	Gradual expansion of urban charging stations; slower progress in rural areas.	Minimal infrastructure; early stages with pilot projects to establish an EV ecosystem.	(Grütter, 2019; Kohli, 2024)
Manufacturing	Globally dominant EV production driven by firms like BYD and Yutong, emphasizing innovation in AI and battery technology.	Local manufacturing encouraged under FAME schemes but lags in global competitiveness; reliance on subsidies to reduce costs and enhance capacity.	Reliant on imported vehicles; exploring collaborations for local manufacturing to reduce dependency and costs.	(Bloomberg, 2023; Jain, 2022). (Kohli, 2024).
Public Transport	Shenzhen leads with a 100% electric bus fleet,	Cities like Delhi and Pune have implemented	Dhaka pilots' electric buses to	(Tare, 2021; Avenali, 2024;



*Introduction of E-Buses in Pakistan's Urban Centers*

<b>Category</b>	<b>China</b>	<b>India</b>	<b>Bangladesh</b>	<b>Evidence</b>
	showcasing operational and environmental benefits; targeted for full electrification by 2035.	e-buses under FAME II but face challenges with operations and fleet scalability.	combat severe pollution; dependent on international grants and investments for expansion.	Bloomberg, 2023)