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Electrifying Public Mobility: Pathways, Challenges and Opportunities for Electric Vehicles (with focus on Punjab)

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ABSTRACT

The state of Punjab is at a critical juncture in redefining its mobility systems. With rapid urbanization, rising vehicle ownership and deteriorating air quality, the demand for a sustainable public transport framework has never been greater. This paper examines the role of electric vehicles (EVs), particularly in the public mobility sector, as a transformative pathway for Punjab's transportation future. Drawing from Ludhiana's Comprehensive Mobility Plan (2014), Low Carbon Mobility Plan (2013) and recent insights on electric mobility, this research highlights both the opportunities and barriers in adopting EVs in public transport. The paper concludes with policy recommendations that can help in achieving a modal shift toward sustainable, electrified and equitable mobility.

Keywords: Public Mobility; Electric Vehicles; Electric Buses; E-rickshaws; Punjab; Sustainable Transport; Shared Mobility; Just Transition; Case Study; Low Carbon Mobility; PM-eBus Sewa; Policy Roadmap; Grid Readiness.

INTRODUCTION

In Punjab, A new type of electric vehicle (EV) revolution is unfolding in the hinterlands. This writer had the chance to visit Bathinda, where almost everyone seems to be using electric two-wheelers and electric three-wheelers. When asked, people explained that free electricity of up to 3,00 units has enabled them to adopt EVs. Similar trends have been observed in other parts of the state, driven by growing awareness of the positive implications of EV adoption. The potential for EVs to reduce greenhouse gas emissions can range from 10% to 60%, depending on the type of EV and geographic area. For comparison, an internal combustion engine vehicle (ICEV) emits 120 g/km of CO_2 on a tank-to-wheel basis, which rises to 170–180 g/km later.

India has prioritized electric mobility through the **National Electric Mobility Mission Plan (NEMMP)** and the **FAME (Faster Adoption and Manufacturing of Electric Vehicles) scheme**. The second phase, FAME-II, launched in 2019, allocated significant funds for the procurement of electric buses, charging stations and demand incentives. In 2023, the **PM-eBus Sewa scheme** further accelerated this transition by providing direct financial support for e-bus operations in urban centres. (**Government of India, Prime Minister's Office. (2023, August 16)).**

As of early 2025, India has registered over 5.6 million EVs, with the public mobility sector emerging as a key focus area, particularly for urban transport and last-mile delivery. Electric buses are central to this strategy: under the PM e-Bus Sewa scheme launched in August 2023, 10,000 e-buses are planned with a budget of ₹20,000 crore, complemented by the PM E-DRIVE scheme introduced in September 2024, which adds incentives for over 14,000 e-buses. By August 2025, 7,293 e-buses had been approved across 14 states and four Union Territories. Leading manufacturers include PMI Electro Mobility, Switch Mobility, Olectra Greentech and JBM Auto, while the PM-eBus Sewa Payment Security Mechanism (PSM) intends to provide financial safeguards to support deployment of over 38,000 e-buses in five years. **(Economic Times Auto, 2025).**

India dominates the global market for electric three-wheelers, widely used for last-mile connectivity. In 2024, e-three-wheelers comprised 57% of total three-wheeler sales. Adoption is driven by lower operating costs, rising fuel prices, government incentives and the shift to lithium-ion batteries. Major players include Mahindra Last

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Mile Mobility, Bajaj Auto and Piaggio, along with smaller domestic manufacturers. Charging infrastructure is expanding rapidly, with over 29,000 stations nationwide by August 2025, up from 5,151 in 2022, supported by ₹2,000 crore under PM E-DRIVE. Operators such as Tata Power, Statiq and Indian Oil are building fast-charging corridors. **(Economic Times Energy, 2025).**

Looking ahead, India targets 30% EV penetration by 2030. However, challenges persist limited infrastructure in semi-urban areas, funding gaps and slow advances in battery technology. Global experiences offer lessons: Shenzhen (China) electrified over 16,000 buses by 2017 through subsidies and manufacturing support; Venice (Italy) deployed electric ferries and buses; and Copenhagen (Denmark) integrated EVs with cycling infrastructure. **(Ministry of Heavy Industries, Government of India)**

Despite progress, India's public EV charging remains inadequate. By February 2024, 12,146 charging stations were operational, far short of the 1.32 million required by 2030 (CII estimate). This gap highlights the urgency for private investment, large-scale installation and need of coordinated government planning to address consumer "range anxiety" and enable widespread adoption. (**Confederation of Indian Industry (CII), 2024)**

2. Challenges

2.1 Electric Mobility and National Policy Context

Multiple local reports show depot and charging infrastructure delays that keep the e-buses "on paper." Central allocations matter, but state and city capacity (tendering, land/procurement, grid readiness) determines whether allocations translate to operations. High upfront EV costs, driven mainly by lithium-ion batteries, restrict affordability. Limited driving range, long charging times and shorter battery lifespan further discourage adoption **(Goel, Sharma & Rathore, 2021).** Insufficient charging and recycling facilities also represent institutional gaps.

In Ludhiana, surveys revealed that 36% of car and two-wheeler owners were willing to switch to EVs. Similar efforts are underway elsewhere. (**Government of India, PMO report on EV. (2023, August 16)).** Hyderabad plans to replace diesel buses with electric ones, while Magenta Power is developing charging infrastructure on the Mumbai-Pune highway. The Society of Indian Automobile Manufacturers (SIAM) targets 100% pure EVs for intra-city public fleets by 2030, but for these steps, drastic policy measures have to be implemented.

2.2 Implementation, governance and execution risks

Implementation shortfalls directly affect EV adoption. Poor road quality raises maintenance costs and disrupts depot and corridor planning. For instance, Ludhiana's 2.2 km, 200-ft road between Phullanwal Chowk and Dhandra Road developed potholes and cracks even before completion, and this road could have emerged as laboratory for EV Mobilization. **(Hindustan Times, 2024).** Such governance issues illustrate practical barriers to large-scale EV operations.

2.3 Challenges specific to Electric Vehicle Adoption in Punjab

Electric vehicle adoption in Punjab faces multiple systemic and operational challenges that hinder large-scale uptake. Specialized servicing remains scarce, with limited diagnostic tools, skilled technicians, and spare parts availability, resulting in longer downtimes and reduced consumer confidence. High upfront costs, particularly for buses and commercial fleets, continue to discourage investment despite government subsidies, as the extended payback period remains a deterrent. Public perception further complicates adoption, with widespread doubts regarding performance, battery life and long-term reliability. On the supply side, dependence on critical raw materials such as lithium, cobalt, and nickel exposes the sector to global price volatility, geopolitical risks, and environmental concerns tied to unsustainable mining practices. Battery degradation over time reduces range and efficiency, raising replacement costs and creating recycling challenges. Driving range limitations restrict long-distance usability, especially for logistics and public transport, while prolonged charging durations add to operational inefficiencies for both private and fleet operators. Additionally, meeting stringent safety requirements around battery thermal management, crash resistance, and electrical safety increases design and compliance costs. Punjab's electricity mix heavily reliant on thermal power, integrating EV charging with

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue X October 2025

renewable energy sources, such as solar at depots, is essential to prevent the mere shifting of emissions rather than achieving genuine environmental benefits (IIT Kanpur).

3. Punjab Scenario – Subsidies adoption of EVM Autos can enhance of mobility (Allocation of Buses to Punjab under E-bus Service)

Punjab's adoption is concentrated in e-rickshaws and two-wheelers, while public e-bus deployment is still nascent. Punjab's current strategy emphasizes depot-based overnight charging, where buses return to depots for 4–6 hours of charging.

3.1 Infrastructure and Operations - Ludhiana

Ludhiana requires major grid augmentation, as a 100-bus depot there could add 5–7 MW of demand, necessitating close coordination with the **Punjab State Power Corporation Limited (PSPCL)** and integration with the **Sherpur grid model** to enhance distribution capacity and voltage stability. Under PM e-Seva, 100 buses have been allotted to Ludhiana. Meanwhile, Ludhiana is one of Punjab's largest industrial hubs which have witnessed a **70% increase in EV registrations over two years**, driven by rising fuel costs, environmental awareness, and government incentives.

3.2 Amritsar

Amritsar's public transport system struggles with limited capacity and inefficiencies. The **Bus Rapid Transit System (BRTS)**, launched in 2019, has faced low ridership and weak feeder integration. Yet, it provides a ready-made corridor for deploying e-buses, particularly in heritage-sensitive areas.

By October 2025, Amritsar is set to receive 100 e-buses under the PM-eBus Sewa scheme (40 at Maal Mandi City Bus Workshop and 60 at Verka Bypass BRTS Depot). These buses will act as feeder services to the BRTS network, offering cleaner mobility for residents and pilgrims. Tourist-driven demand makes Amritsar ideal for opportunity-charging stations near the Golden Temple and airport, ensuring uninterrupted services during peak travel seasons. **(The Tribune, 2025).**

3.3 Jalandhar & Patiala

Jalandhar, an industrial hub for sports and leather goods and Patiala, known for education and heritage, face similar challenges: congestion, rapid motorization and declining bus ridership.

Electrification strategies here focus on integrating e-buses with informal Intermediate Public Transport (IPT). Without this integration, new services risk replicating the failures of past bus initiatives. Jalandhar has been allocated 97 e-buses, while Patiala will operate 50 under the PM-eBus Sewa scheme.

3.4 Comparative Overview of Case Studies

City	Allocation of E-Buses	Mobility Model	Infrastructure Focus	Strengths	Challenges
Ludhiana **(Industrial Hub)**	100 e-buses (PM-eBus)	Depot-based charging model	Large depots, high-capacity grid feeders (5–7 MW load per 100 buses)	High commuter demand; potential for industrial workforce mobility	Grid readiness; weak integration with IPT; public bus ridership <15% of trips

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue X October 2025

Amritsar **(Tourist City)**	100 e-buses (PM-eBus)	Corridor-based (BRTS + Tourist Corridors)	Charging infra at BRTS terminals and near heritage zones	High visibility along Golden Temple and tourist routes; air quality benefits	BRTS underutilization; IPT integration weak; seasonal demand peaks
Jalandhar **(Medium Industrial City)**	97 e-buses (PM-eBus)	Integration-focused (Bus + IPT)	Depot charging at bus terminal; feeder links to markets	Manageable fleet size; potential for feeder integration	Unregulated IPT competition; limited bus network
Patiala **(Educational/Heritage City)**	50 e-buses (PM-eBus)	Small-fleet transformation model	Single depot charging cluster; smaller corridors	Even small fleets can transform coverage; strong potential for university routes	Low base of bus ridership; dependence on informal autos

Source: CMP-Ludhiana-Final-Report and City-Report-Ludhiana

METHODOLOGY

Document Review and Synthesis: Policy reports, planning documents and academic articles were analyzed to identify trends, challenges and opportunities in EV adoption.

Comparative Case Study Analysis: Punjab's urban centers (Ludhiana, Amritsar) were compared with international examples (Shenzhen, Venice, Copenhagen) to extract context-sensitive lessons.

Analytical Framework: The study examines sustainable mobility across three dimensions: **environmental sustainability**, assessing emissions, air quality and battery lifecycle; **socio-economic equity**, covering affordability, accessibility and workforce transition; and **institutional capacity**, evaluating policies, governance, and infrastructure readiness.

This multi-dimensional approach ensures the research is not merely descriptive but also analytical, offering practical pathways for accelerating electrified public mobility in Punjab.

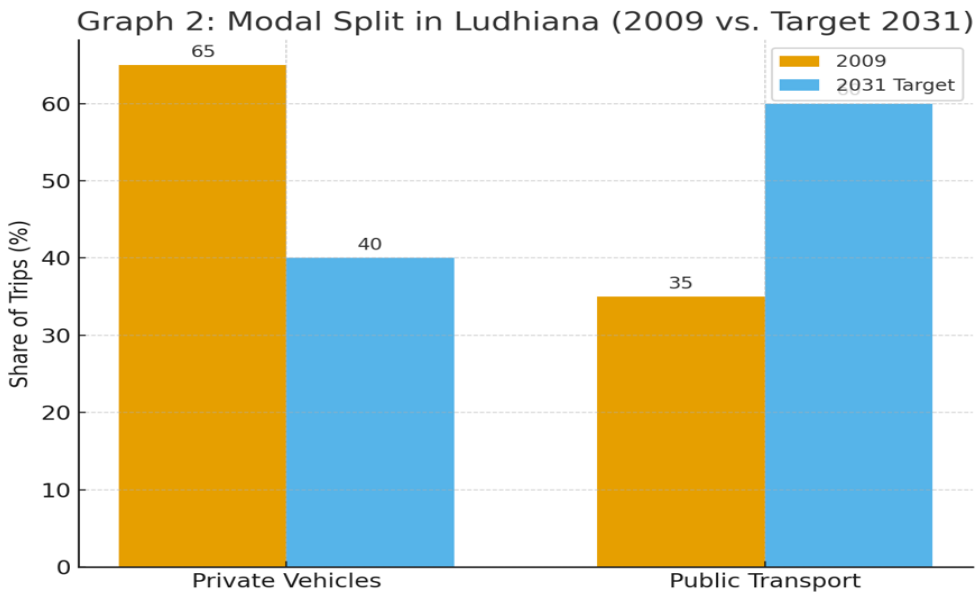
5. Findings and Analysis

5.1 Modal Split

Public transport accounts for only 35% of motorized trips, far below the 60% benchmark. Without intervention, private vehicle dependence will continue to dominate.

Graph: Modal Split in Ludhiana (2009 vs. Target 2031)

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue X October 2025



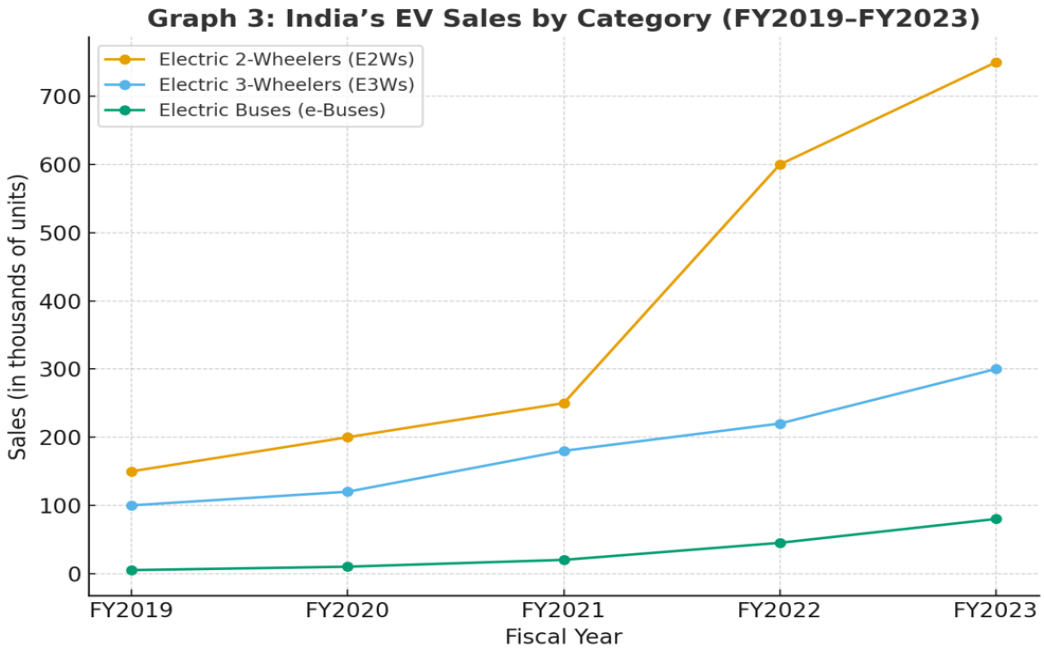
- 2009: 65% private vehicles, 35% public transport
- 2031 (Target): 40% private, 60% public transport (with EVs as backbone)

Source: Author's visualization.

5.2 EV Adoption Trends in India and Punjab

Graph : India's EV Sales by Category (FY2019–FY2023)

(Line graph showing exponential growth, dominated by E2Ws, with a slow rise in e-buses.)



Source: Just Transition Research Centre (2024); Ministry of Heavy Industries, Government of India (2019, FAME-II Notification); Author's visualization.

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue X October 2025

5.3 Pathways for Punjab's Mobility Transition

By 2035, three scenarios emerge:

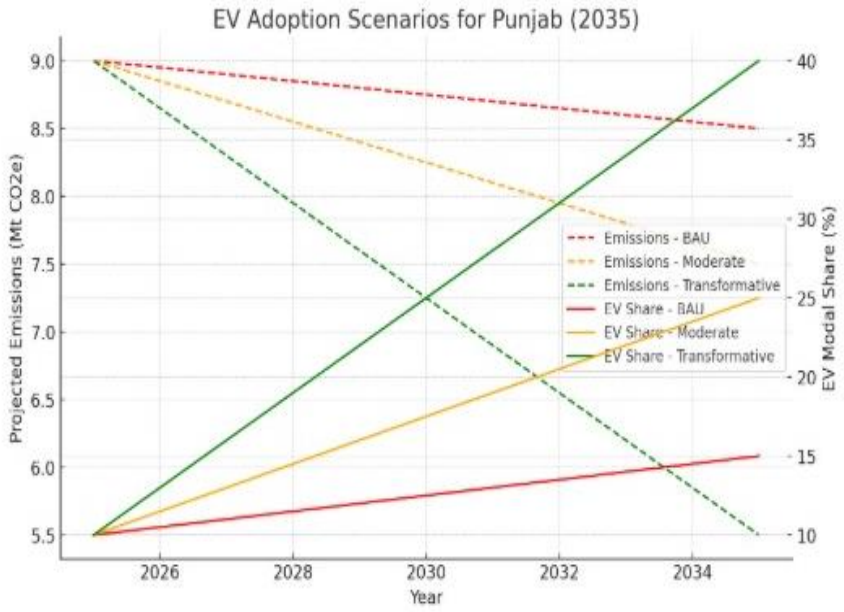
Business-as-Usual (BAU): EV uptake limited to private two-wheelers and e-rickshaws; public buses remain diesel-based, worsening congestion and emissions.

Moderate Transition: Gradual introduction of e-buses in Ludhiana, Chandigarh and Amritsar, along with formalization of e-rickshaws. Emissions stabilize but accessibility gaps persist.

Transformative Transition: State-led push to electrify 50% of the bus fleet by 2035, integrate e-rickshaws into formal systems, promote e-bikes and expand renewable-powered charging networks.

Graph: EV Adoption Scenarios for Punjab (2035)

(Line chart comparing emissions and modal shares under BAU, Moderate and Transformative scenarios.)



Source: State Energy Efficiency Action Plan (SEEAP), Punjab

6. Policy Recommendations

6.1 Enhance Public EV Infrastructure and Accessibility

Strengthening public EV infrastructure is vital for wider adoption. Policies should prioritize fast charging stations in cities, towns and along highways, supported through public–private partnerships and renewable energy integration. Focused investment in transit hubs, corridors and dense neighborhoods can reduce range anxiety and improve convenience. Affordable tariffs and inclusion of charging points in smart city and housing projects will further build public confidence in shifting to electric mobility.

6.2 Promote Shared and Public Mobility

The Just Transition Research Centre (2024) found EV adoption fastest in two- and three-wheeler segments, while public mobility lags due to high costs, weak infrastructure and institutional inertia. Shared mobility offers a pathway to accelerate adoption. Car-sharing, e-rickshaw pooling and micro-transit reduce costs and expand access, especially for those unable to purchase EVs. In Punjab, electrification of these services presents strong potential. Public buses should target 50% electrification by 2035, leveraging FAME-II subsidies, leasing/PPP models, and phasing out older diesel buses first.

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue X October 2025

6.3 Develop Charging Infrastructure

EV corridors should be developed along highways with fast-charging hubs at depots, terminals, and logistics centers. At least 30% of charging capacity should come from renewables, especially rooftop solar. Urban local bodies must mandate EV-ready parking in all new projects and integrate battery swapping for e-rickshaws.

6.4 Strengthen Institutional Coordination

Establish a Unified Metropolitan Transport Authority (UMTA) in major cities for integrated EV planning. At the state level, a dedicated EV Commission should coordinate stakeholders, publish annual scorecards and ensure accountability.

6.5 Support Manufacturing and Localization

India's PLI must be leveraged schemes to build a self-reliant EV ecosystem. Advanced Automotive Technology (₹25,938 crore) and Advanced Chemistry Cell Battery Storage (₹18,100 crore) incentivize domestic EV and battery manufacturing. A minimum 50% Domestic Value Addition (DVA) ensures supply chain localisation, complemented by GST reduction, tax waivers and PM e-DRIVE. Ludhiana and Jalandhar's auto-component base can help Punjab emerge as a manufacturing hub for EVs and batteries.

6.6 Grid Readiness and Energy Integration

In Punjab, PSPCL must map EV hotspots and upgrade distribution capacity. Statewide rollout should include highway fast chargers and clustered AC chargers in towns. Solar-integrated depots and vehicle-to-grid (V2G) pilots can reduce peak load pressures and emissions. Similar efforts can be adopted in other states too.

6.7 Skills Development and Battery Lifecycle Management

Launch an EV Skills & MSME Support Programme to train 5,000 technicians and provide grants to 200 MSMEs adopting EV fleets. Retraining informal mechanics will protect livelihoods while building capacity for the new mobility economy. Introduce an Extended Producer Responsibility (EPR) framework for batteries covering recycling, refurbishment and second-life applications, creating green industry opportunities.

CONCLUSION

Electric vehicles present a transformative opportunity to reshape public mobility in India especially in Punjab. By prioritizing shared and public EVs such as buses, e-rickshaws and e-bikes, the state can simultaneously cut emissions, reduce congestion, improve accessibility for low-income groups and foster industrial growth.

However, electrification must not be viewed as merely a technological shift. It requires institutional reform, integration of renewable energy and inclusive policies that ensure affordability and workforce reskilling. Only then can the transition be both sustainable and equitable.

The policy roadmap outlined in this study provides a clear direction: set ambitious yet achievable targets, develop renewable-powered charging corridors, strengthen governance structures and leverage industrial strengths to build local EV supply chains. Equally important is supporting communities and workers through skill development and affordable mobility programs, ensuring a Just Transition.

Looking ahead, advancements in battery efficiency, ultra-fast and wireless charging and vehicle-to-grid (V2G) systems will further accelerate adoption. Coupled with stakeholder engagement and public awareness, these innovations can future-proof India's mobility transition.

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