

Issue Brief | September 2025

India's E-bus Initiatives

Job Creation, Adoption Challenges,
and Policy Pathways

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Suggested citation: Jha, Anannya, Divyanshu Yadav, Aditya Swarankar, Saoni Sanyal, Krishna Khanna, and Himani Jain. 2025. *India's E-bus Initiatives: Job Creation, Adoption Challenges, and Policy Pathways*. New Delhi: Council on Energy, Environment and Water.

Disclaimer: The views expressed in this report are those of the authors and do not reflect the views and policies of the Council on Energy, Environment and Water.

Cover image: iStock. For illustrative purposes only.

Peer reviewers: The authors of this study would like to thank the following reviewers for providing critical feedback and comments to refine this report: Dr Shalini Sinha, Professor and Dean of Faculty of Planning, CEPT University; Aswathy Dilip, South Asia Director, ITDP India; Rupa Nandy, Head of India RO, Union Internationale des Transports Publics (UITP) India, and Gagan Sidhu, Director of the CEEW Green Finance Centre.

Publication team: Purnima P. Vijaya (CEEW), Archana Chandrashekar (CEEW), Alina Sen (CEEW), The Clean Copy, Twig Designs, and FRIENDS Digital Colour Solutions.

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Report—September 2025
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Acknowledgment

The authors would like to express their sincere gratitude to the **Association of State Road Transport Undertakings (ASRTU)** for encouraging the work on the project and extending their continued support throughout its development. We especially thank **Dr T Surya Kiran** (former executive director of ASRTU) for his constant guidance and support in shaping this study.

We deeply appreciate **Shakti Sustainable Energy Foundation (Shakti)**, our knowledge partner, for their guidance and support throughout this study. Special thanks to **Mr Rishabh Sethi** (Programme Manager, Shakti) for serving as the technical contributor to the study and providing valuable insights.

Further, we are grateful to the numerous individuals, institutions, and industry partners who granted us permission to document the case study and generously shared information, data, and technical insights that contributed significantly to this study.

We also thank **Mr Biju Deka** (Chief Engineer, ASTC), **Mr Jyotirmoy Deka** (Assistant Engineer, ASTC), **Multitech Engineering, RB Enterprises, CHALO** team, and the operations and maintenance staff in Guwahati for their cooperation and inputs. From Surat, we are thankful to the Managing Director, Surat Sitalink, **Mr Praveen Prasad** (General Manager – O&A, Surat Sitalink), the Depot Managers—especially **Mr Ronak Desai** and the OEMs, including **GreenCell, Olectra, and JBM**—for their valuable support.

We appreciate the contributions of **Mr Sanyam Gandhi** and his team from Chartered Speed, **Mr Santosh Thakur**, and **Mr Aniruddha Oka** from Kalyani Powertrain Limited. Our thanks also go to **Mr Pramod Sharma** from SUN Mobility and **Mr Sumit Barat** and **Mr Arpit Agrawal** from NueGo (GreenCell Mobility) for their time and insights.

We are grateful to **Mr Amrit Abhijat, IAS, Additional Chief Secretary, Urban Development Department (UDD)**, Uttar Pradesh, and **Mr Jaideep Verma, Joint Director, Directorate of Urban Transport, Uttar Pradesh**, for their support in covering the Maha Kumbh preparations.

Lastly, we would like to acknowledge the contributions of our colleagues at CEEW, especially **Udit Narayan, Chris Teresa Varghese, and Dharshan Mohan**, for their valuable support throughout this study.

Thank you all for your generosity and support in this endeavour.

The authors

Foreword



सड़क परिवहन
एवं राजमार्ग मंत्रालय
MINISTRY OF
**ROAD TRANSPORT
AND HIGHWAYS**



Shri Mahmood Ahmed, IP&TAFS

Additional Secretary

Ministry of Road Transport & Highways

Buses are a cornerstone of India's commitment to accessible, equitable, and sustainable mobility. As the Ministry of Road Transport & Highways advances the National Electric Bus Programme, and as states adopt innovative business and operational models, this transformation represents more than just a technological shift. It marks a decisive step toward shaping a cleaner, more inclusive, and energy-resilient future for millions across both rural and urban landscapes.

The journey toward electrified public transport is driven not only by environmental imperatives, but also by our responsibility to enhance social and economic empowerment. Affordable, reliable bus services connect people to education, livelihoods, and essential services. The adoption of electric buses is already catalysing new employment opportunities, boosting domestic manufacturing, and fostering innovation within India's dynamic mobility ecosystem.

This report by the Council on Energy, Environment and Water (CEEW) captures these transitions through rich data, case studies, and sector insights. It documents not only the pioneering initiatives of states, cities, and transport undertakings, but also the experiences of operators, manufacturers, and workers shaping this shift on the ground. In doing so, it illustrates the power of collective action—from policymakers and engineers to city planners, drivers, and passengers—in building a cleaner, more efficient, and forward-looking public transport system for India.

I am confident that the evidence and narratives presented in this publication will inspire continued collaboration and innovation, while reinforcing our shared vision for a sustainable, connected, and prosperous India.

Foreword



Shri Sudhendu J. Sinha
Advisor (E-Mobility)
NITI Aayog

India's Bus Sector stands at the intersection of economic opportunity, energy resilience, and environmental stewardship. India's net zero commitments and vision to transform public transport are anchored by buses. Buses are not just vehicles; they usher in clean mobility, are engines of job creation, while supporting access to millions of livelihoods, children and youth's education across urban and non-urban landscapes.

The energy transition in the bus sector is equally significant. By diversifying energy sources—embracing electricity and Hydrogen buses—we move closer to energy security, and conserve valuable foreign exchange. Every electric, CNG, and advanced diesel technology bus on Indian roads is a step towards cleaner air, reduced greenhouse gas emissions, and a more resilient energy future.

This Report is a journey of collaboration and partnerships with State and City governments which play a crucial role on the frontlines—implementing bus reforms, fostering public-private partnerships, and driving innovations in service quality, gender integration, and operational efficiency.

The case studies and their analysis in this Report highlight the leadership, innovations from state governments and private sector partners. I commend the Council on Energy, Environment and Water (CEEW) and Sustainable Mobility team for this comprehensive and timely documentation. I am sure it will mark a milestone in India's bus sector, but also serves as a valuable resource for policymakers, practitioners, and industry leaders.

Foreword



Shri K.N Bhutia

Executive Director

Association of State Road Transport Undertakings (ASRTU)

India's bus sector stands at an important transition phase. The inclined efforts of the Government of India's towards enhancing bus services, energy security and clean energy usage are seen in PM E-drive, PM E-bus sewa, and PLI schemes. The bus sector, supplemented with the electrification of buses, offers an opportunity to reshape how millions of people travel daily. This report—India's Early Bus Electrification Initiatives—presents a just and in-depth documentation of how India's bus sector is transitioning to electric buses, other evolving technologies in various states and regions, and their implication on future jobs.

This report offers an assessment of innovative initiatives by city transport undertakings to tackle on-ground barriers like battery degradation and depot planning. This study has showcased strategic modelling with on-the-ground case studies, and interviews with officials. It acknowledges the key challenges—like high upfront costs to fragmented charging infrastructure and range limitations—and shows how local leadership, innovative contracts, and emerging technologies are responding with agility.

I commend the Council on Energy, Environment and Water (CEEW) Mobility team for producing this thoughtful publication. It will serve as a valuable resource for policymakers, industry leaders, city planners, and especially STUs to drive India's sustainable mobility.

About CEEW

The **Council on Energy, Environment and Water** (CEEW) is one of Asia's leading not-for-profit policy research institutions and among the world's top climate think tanks. The Council uses **data, integrated analysis, and strategic outreach to explain—and change—the use, reuse, and misuse of resources**. The Council addresses pressing global challenges through an integrated and internationally focused approach. It prides itself on the independence of its high-quality research, develops partnerships with public and private institutions, and engages with the wider public. CEEW is a strategic/ knowledge partner to 11 ministries for India's G20 presidency.

The Council's illustrious Board comprises Mr Jamshyd Godrej (Chairperson), Dr Suresh Prabhu, Mr Amitabh Kant, Mr S. Ramadorai, Mr Montek Singh Ahluwalia, Dr Naushad Forbes, Dr Janmejaya Sinha, and Ms Vinita Bali. The 380+ strong executive team is led by Dr Arunabha Ghosh. CEEW has repeatedly featured **among the world's best managed and independent think tanks**.

In over 15 years of operations, The Council has engaged in 500+ research projects, published 513+ peer-reviewed books, policy reports and papers, created 220+ databases or improved access to data, advised governments around the world 1400+ times, promoted bilateral and multilateral initiatives on 180+ occasions, and organised 650+ seminars and conferences. In July 2019, Minister Dharmendra Pradhan and Dr Fatih Birol (IEA) launched the CEEW Centre for Energy Finance, which is now known as CEEW Green Finance Centre (CEEW-GFC). In August 2020, Powering Livelihoods a CEEW and Villgro initiative for rural start-ups—was launched by Minister Piyush Goyal, Dr Rajiv Kumar (then NITI Aayog), and H.E. Ms Damilola Ogunbiyi (SEforAll).

The Council's major contributions include: Informing India's net-zero goals; work for the PMO on accelerated targets for renewables, power sector reforms, environmental clearances, Swachh Bharat; pathbreaking work for India's G20 presidency, the Paris Agreement, the HFC deal, the aviation emissions agreement, and international climate technology cooperation; the first independent evaluation of the National Solar Mission; India's first report on global governance, submitted to the National Security Advisor; support to the National Green Hydrogen and Green Steel Missions; the 584-page National Water Resources Framework Study for India's 12th Five Year Plan; irrigation reform for Bihar; the birth of the Clean Energy Access Network; the concept and strategy for the International Solar Alliance (ISA); the Common Risk Mitigation Mechanism (CRMM); India's largest multidimensional energy access survey (ACCESS); critical minerals for Make in India; India's climate geoengineering governance; analysing energy transition in emerging economies, including Indonesia, South Africa, Sri Lanka, and Viet Nam. CEEW published Jobs, Growth and Sustainability: A New Social Contract for India's Recovery, the first economic recovery report by a think tank during the COVID-19 pandemic.

The Council's current initiatives include: State-level modelling for energy and climate policies; consumer-centric smart metering transition and wholesale power market reforms; modelling carbon markets; piloting business models for solar rooftop adoption; fleet electrification and developing low-emission zones across cities; assessing green jobs potential at the state-level, circular economy of solar supply chains and wastewater; assessing carbon pricing mechanisms and India's carbon capture, usage and storage (CCUS) potential; developing a first-of-its-kind Climate Risk Atlas for India; sustainable cooling solutions; developing state-specific dairy sector roadmaps; supporting India's electric vehicle and battery ambitions; and enhancing global action for clean air via a global commission 'Our Common Air'.

The Council has a footprint in over 20 Indian states, working extensively with 15 state governments and grassroots NGOs. Some of these engagements include supporting power sector reforms in Uttar Pradesh, Rajasthan, and Haryana; energy policy in Rajasthan, Jharkhand, and Uttarakhand; driving low-carbon transitions in Bihar, Maharashtra, and Tamil Nadu; promoting sustainable livelihoods in Odisha, Bihar, and Uttar Pradesh; advancing industrial sustainability in Tamil Nadu, Uttar Pradesh, and Gujarat; evaluating community-based natural farming in Andhra Pradesh; and supporting groundwater management, e-auto adoption and examining crop residue burning in Punjab.

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Image: CEEW

Executive summary

Buses are an integral mode of transport for Indian road users, with nearly 390 million daily commuters depending on different types of bus services (Gadepalli 2024). Diesel buses dominate the market, accounting for nearly 95 per cent of yearly (more than 90,000) units sold (Vahan Dashboard n.d.). As per the latest all-India survey on diesel and petrol sales, buses accounted for approximately 10 per cent of the total diesel consumption in the country (MoPNG 2014), contributing significantly to India's oil imports. In contrast, merely 9,700 electric buses (e-buses) have been registered in the last decade. The e-bus market is growing at a compound annual growth rate (CAGR) of ~65 per cent, with sales driven by e-bus programmes and government incentives.

E-buses have the potential to influence India's energy security objectives while meeting its decarbonisation and pollution mitigation efforts. The study analyses evolving bus market trends of use cases, regional sales, fuel choice, and manufacturers. To identify the future potential for bus electrification, we estimate the bus stock and sectoral jobs by 2047 under a business-as-usual (BAU) scenario and its likely fuel split. We identify learnings, challenges, and opportunities from the country's early e-bus initiatives through eight case studies.



E-bus registrations in India are growing rapidly at a CAGR of around 65%, with nearly 9,700 buses registered till date.

Key findings: Jobs, market and original equipment manufacturers (OEMs)

Buses will continue to serve nearly one-fourth of the Indian population (457 million or 45.7 crore passengers) daily in 2047 in the BAU case. CEEW's Transportation Fuel Forecasting Model (TFFM) forecasts that 3.34 million (33.4 lakh) buses will be on-road¹ by 2047 in the BAU scenario.

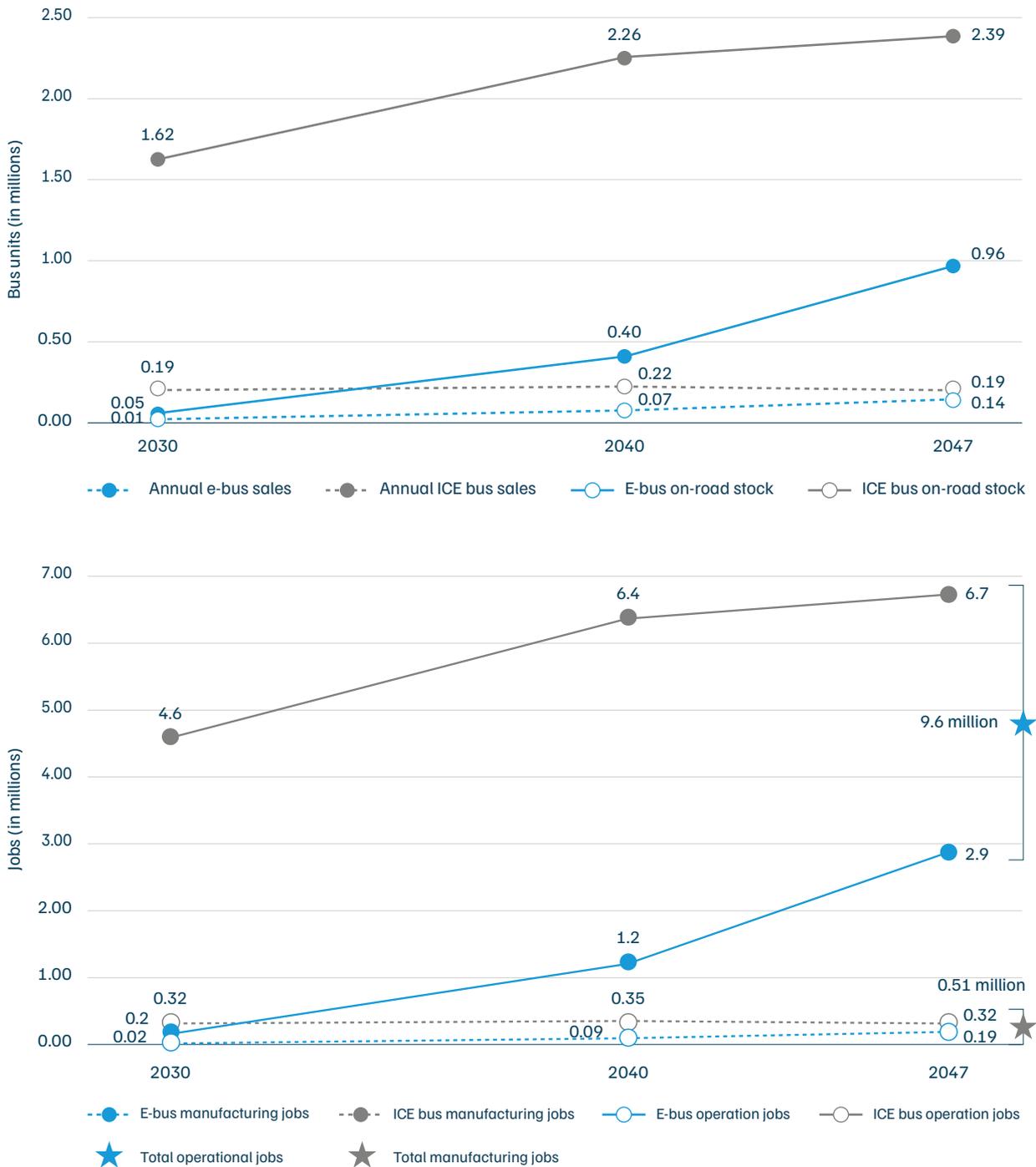
We find that, on average, the demand for 1 additional bus creates approximately 4-5 new jobs in the market. Therefore, we estimate that the bus ecosystem will generate approximately **10.1 million (1.01 crore) jobs by 2047, with 95 per cent of these jobs in operations and 5 per cent in manufacturing.**



E-buses are set to transform India's bus sector; however, they will only account for around 42% of annual new bus registrations by 2047, indicating a need for additional policies

1. On-road stock: The total number of vehicles plying on the road. For this study, these are estimated by using a survival curve that eliminates the fleet disposed of due to reaching end of life or becoming unfit for operation.

Figure ES1. The bus sector is projected to generate approximately 9.6 million operational jobs and 0.51 million manufacturing jobs by 2047



Source: Authors' Analysis

We estimate that, under a business-as-usual (BAU) scenario, **e-buses will account for 42 per cent of annual sales by 2047.**

To leapfrog the benefits accrued to e-bus adoption and to catapult the e-bus markets, there is an urgent need to address existing barriers and accelerate their adoption.

- **Limited variants of smaller e-buses:** Typically, buses are considered medium and heavy-category vehicles. Our estimates show that the light passenger vehicle category buses form about 30 per cent of the buses registered on the Vahan portal. Thus, the market needs cheaper, cleaner variants of such smaller buses.
- **School e-buses market untapped:** Our analysis shows that e-bus uptake has been limited to intra-city operations. However, bus sales data for 2023–2024 show that school and college buses account for about one-third of the market, remaining the largest use case. We find that the lower daily utilisation of school buses makes e-buses financially unviable for such operations. Hence, more affordable e-bus variants tailored for educational use are needed.
- **Regional focus is needed:** The data highlights geographic variations across states in terms of bus sales volumes. Around 52 per cent of all buses registered in 2023–24 were concentrated in six states: Maharashtra (13.4 per cent), Tamil Nadu (9.6 per cent), Karnataka (9 per cent), Haryana (7.8 per cent), Madhya Pradesh (6.5 per cent), and Rajasthan (6.3 per cent). Early incentives and mandates for these states can catalyse the country's e-bus ecosystem.
- **Leverage consolidated bus market to nudge standardisation and interoperability:** Our analysis notes that the Indian bus market remains fairly consolidated, with the top five legacy companies accounting for 91.3 per cent of registrations across diesel, CNG, and electric buses. It is imperative to create standards for sharing battery management data and interoperability of chargers.
- **Leveraging the increased competition between suppliers to plan mandates:** Our analysis of bus registration data shows that traditional internal combustion engine (ICE) bus manufacturers are increasingly shifting to e-bus production. In 2024, the number of OEMs manufacturing e-buses surpassed those producing diesel buses for the first time, supported by the Indian government's 2021 product-linked incentive (PLI)-Auto scheme. Notably, newer OEMs have captured about 30 per cent of the e-bus market, signalling their influence in this segment. The growing supply chains make it possible to mandate e-buses in select use cases.

E-bus innovative practices

Our previous studies note that lack of public charging, high upfront costs, uncertainty around battery life and range anxiety remain key challenges to deploying electric buses in India (Khanna et.al. 2024). We identified a pool of 20 case studies where specific initiatives have been undertaken to tackle such challenges on the ground. From this pool, eight case studies were selected based on multiple criteria, including thematic diversity, geographic distribution, availability of reliable data for analysis, and necessary permissions from local stakeholders (Table ES1). The team spent 5-7 days at each case study site, collating site observations and conducting 4-5 in-depth interviews to validate the solution and its impacts.

Table ES1. Key e-bus initiatives in India (2018–2025) that are developing innovative solutions to address sectoral challenges

Year	Local e-bus innovations and their impacts	Use cases on which innovation is applied	E-bus Initiative
2018	<p>Battery swapping as an alternative to fixed charging</p> <p>Pilots from Ahmedabad BRT have informed the next-gen development of battery swapping technology and stations, leading to an overall reduction in swapping time and costs. The battery swap models offer a cheaper total cost of ownership (TCO)² compared to fixed battery e-buses.</p>	Intra-city bus rapid transit (BRT) pilot operations	Ahmedabad Janmarg Limited, Ahmedabad
2019	<p>Operations management to address battery degradation</p> <p>Indore's efforts to readjust the charging schedule through opportunity charging have helped them achieve their daily operational kilometres with ease, countering higher battery replacement costs and battery degradation challenges.</p>	Intra-city operations under the <i>Faster Adoption and Manufacturing of Hybrid and Electric Vehicles I</i> policy (FAME I)	AICTSL, Indore
2021	<p>E-depot planning to reduce dead kilometres³</p> <p>Surat's efforts to strategically decentralise charging infrastructure have reduced dead kilometres by nearly 50 per cent, highlighting the importance of effective depot planning.</p>	Intra-city BRT operations (electric)	Surat Sitilink Limited, Surat
2022	<p>Alternate business models to cater to corporates</p> <p>Their rising interest in Scope 3 declarations⁴ is driving corporate interest in employee transport. Chartered Speed's case shows that e-buses for employee transport are a lucrative business model due to assured contracts</p>	Private staff bus operations	Chartered Speed Private Limited, Gandhinagar

2. TCOs refer to total cost of ownership of a bus covering both the operational and capital cost associated with its use through its end-of-life.

3. 'Dead kilometres' refers to the distance travelled by a public transit vehicle without any boarding//alighting of passengers, typically when moving from a depot to the starting point of a route or from the ending point of a route to the depot.

4. Scope 3 declaration refers to the reporting of indirect greenhouse gas (GHG) emissions that occur across a company's value chain but are not owned or directly controlled by it. These include emissions from activities such as daily commuting of employees, remote work energy use, extraction and transportation of raw material etc. While reporting Scope 3 is currently voluntary, it is essential for capturing an organisation's full climate impact.

Year	Local e-bus innovations and their impacts	Use cases on which innovation is applied	E-bus Initiative
2023	<p>Gender inclusion in driving jobs</p> <p>NueGo's inter-city travel services provide a unique business case for private inter-city e-bus operations. The ease of driving e-buses compared to traditional ICE buses has led to the integration of women drivers.</p>	Private inter-city operations	NueGo, Delhi NCR
2024	<p>Rental models of operation</p> <p>New operational models like Guwahati's fixed-cost operating model, where it utilised <i>Smart Cities Mission</i> funds to procure e-buses, and a rental-based operation was introduced to attract private investment into running the intra-city e-bus operations.</p>	Intra-city stage carriage operations	ASTC, Guwahati
2024	<p>Retrofitting of buses to reduce the capital cost of e-buses</p> <p>Retrofitting models offered by Kalyani Powertrain Limited highlight that technological innovations and retrofitment of older vehicles reduce capital costs associated with e-buses.</p>	School buses	Kalyani Powertrain Limited, Pune
2025	<p>Leveraging state-wide charging networks</p> <p>Uttar Pradesh leveraged the state-wide network of city e-buses and charging infrastructure to cater to mass movements in Prayagraj for 45 days during Mahakumbh by establishing temporary depots and charging stations at three locations. City bus services travelled more than 600- 800 kilometres using the current state-wide charging infrastructure.</p>	Occasional large pilgrimage, religious and festival demands	Prayagraj City Transport Services Limited, Prayagraj

Source: Authors' compilation

Recommendations

Although e-buses are set to transform India's bus sector, the sector is still in its nascent stages and faces several barriers that require strategic solutions and targeted policies. Coordinated efforts are needed to catapult technology adoption. Thus, we suggest the following three-pronged approach to strengthen this nascent sector.

- **Facilitate mandatory data sharing on battery utilisation:** The lack of data from OEMs regarding charge cycle utilisation increases fleet operators' uncertainty. Thus, policymakers must create the required regulatory frameworks, such as battery aadhar/ battery passport, to enable battery data sharing among operators. Being a publicly owned asset, the state transport undertaking- (STU) / city transport undertaking- (CTU)⁵ -run e-buses can be the perfect pilot case for implementing such systems before a complete roll-out is put in place. This will help create a more robust battery insurance ecosystem and improve the secondary market value of e-buses. Further, the government must support and fast-track the adoption of proven technologies like battery swapping and retrofitted e-buses.
- **Promote shared charging infrastructure and interoperability of chargers:** While the lack of depots and infrastructure remains a concern for the bus sector, inadequate charging infrastructure for e-buses further limits demand. Effective operations, combined with strategic investment in charging infrastructure, can help overcome range limitations, as highlighted in Surat, at the city level, and Uttar Pradesh, at the state level. However, it is critical to mandate charging interoperability among bus OEMs to optimise investments, enhance utilisation, and make operations seamless.
- **Mandate e-buses in niche use cases:** E-bus uptake has been limited to intra-city operations, although private operators constitute 80 per cent of the market. Several private operators have shown that e-buses are techno-economically viable for niche operations like inter-city luxury travel, intra-city public transport, and staff mobility. Based on these findings, the government must consider mandating e-bus usage for limited area-based operations such as special economic zones (SEZs), eco-sensitive or tourist zones, metro-feeder services, and airport-tarmac operations.

Way forward

The study presents strategic and innovative cases that feature solutions to deal with e-bus deployment and operational challenges. We plan to further deep-dive into high-potential use cases over their life to document and study in detail various aspects, including battery cycles, degradations, and viable financial and operational models. While documenting case studies supplies adequate data and real-life situations to recalibrate financial and operational models, addressing these issues will require coordinated efforts from national and state governments, transit agencies, OEMs, and service providers.

5. Public transport agencies in India operate in three formats – state transport undertakings (STUs), city transport undertakings (CTUs), and as special purpose vehicles (SPVs) – to provide bus-based public transit services within a designated region/ route. Most buses operated by transport agencies are public/stage carriage buses – these are public bus services that operate on fixed routes, picking up and dropping off passengers at designated stops, and charging a set fare per passenger.



1. Introduction

Transportation is the backbone of economic development and social welfare, connecting communities, jobs, education, and essential services (Kaiser and Barstow 2022). In India, buses play a fundamental role in providing this connectivity by ferrying approximately 16 per cent of the country's workforce (Census 2011). As the Indian economy grows and cities expand rapidly, ecological concerns are intensifying (Nagendra et.al. 2013). Therefore, efficient, flexible, and resilient bus-based public transport has become an urgent need.

In 2014, buses accounted for nearly 10 per cent of the total diesel consumption in the country (MoPNG 2014), contributing significantly to India's oil imports. However, according to the government-set Service Level Benchmarks (SLBs), cities should have at least 600 buses per million population (60 buses per lakh) to boost the use of public transport and reduce private transport use (MoHUA n.d.), which consumes almost 95 per cent of the petrol and 13 per cent of the total diesel imported (MoPNG 2014). Most mega-cities in India, excluding Bengaluru, have around 200-400 buses per million (20–40 buses per lakh), highlighting a significant gap nationwide (ITDP 2022). Thus, there is an urgent need to expand bus-based public transport while reducing buses' overall reliance on fossil fuels.

Initiatives like the *National Electric Mobility Mission Plan (NEMMP)* launched in 2013, the *Faster Adoption and Manufacturing of Hybrid and Electric Vehicles (FAME)* schemes (2015-2024), and the *PM-eBus Sewa* scheme 2023, reflect the government's strong commitment to a clean energy transition. These schemes have helped increase the deployment of intra-city buses since 2015. By 2024, India had registered 9,714 electric buses (e-buses), with a compound annual growth rate (CAGR) of over 65 per cent. However, internal combustion engine (ICE) buses, i.e., those that run on fossil fuels, still dominate the ecosystem, with diesel and CNG buses accounting for 93.5 per cent and 4.9 per cent, respectively, of the total buses registered in 2024 (Vahan Dashboard n.d.).



Government schemes such as NEMMP, FAME, and PM-eBus Sewa have increased the deployment of electric buses in India

The continued prevalence of several challenges in e-bus operations, such as a lack of public charging infrastructure on highways and transit hubs (Sharma 2023; Khurana 2024), long charging times, high upfront costs for private operators, and limited access to subsidies (Kohli and Gowande 2024), explain their limited uptake. Also, concerns regarding battery longevity and replacement expenses, challenges related to driving range (Bharadwaj 2023), insufficient expertise within the maintenance network, and the minimal profitability of longer trips under 400 km of daily vehicle usage further impede the use of e-buses for inter-city journeys (Khanna et al. 2024).

E-buses are set to alter the landscape of the bus sector in India. However, the transition is still in a nascent stage, and original equipment manufacturers (OEMs) and operators are focusing on developing innovative solutions to solve prevailing barriers and are undertaking bold pilots to overcome them. Therefore, it is crucial to understand these unique initiatives and assess their impact.

Chapter 2 provides an overview of the e-bus sector, its market contours, and its estimated future trajectory compared to ICE buses. We discuss the potential for job creation within the e-bus sector and future e-bus trends in Chapter 3. Chapter 4 features eight unique e-bus cases from different geographies. These case studies document innovative bus electrification efforts by city transport undertakings (CTU) and private operators, highlighting the innovative solutions developed to solve local challenges and the key learnings in operations, infrastructure, and workforce management. The report concludes with findings and conclusions gathered for bus OEMs, operators, and policymakers.

Methodology

The methodology for this report involves a multi-faceted structure for the three sections.

- Analysis of bus market:** The study uses registration data from Vahan database to assess the changes in the bus market. For future projections, it leverages the CEEW–TFFM to estimate the annual sales of bus stock till 2047. The model estimates future energy demand in the road transportation sector by evaluating how factors such as vehicle stock, total cost of ownership, infrastructure development, and policy scenarios influence the transition to cleaner fuels. It incorporates all relevant variables that could impact this transition, including fuel pricing, infrastructure availability, and vehicle costs. To estimate the bus stock for 2047, the model applies historical vehicle registration trends from the Vahan database and uses a Gompertz curve—correlated with GDP and population growth—to project vehicle sales from 2024 to 2050. Details on the model’s assumptions and methodology are provided in Annexure 1.
- Jobs estimation:** For job estimation in the bus sector, projections of bus stock and new annual registrations are derived using the TFFM. The manufacturing job coefficient per unit is sourced from Europe’s mature electric MHDV market (as reported by BCG), while the operational job coefficient is calculated based on the aggregated weighted proportion of staff requirements across different use cases for ICE and e-buses. These coefficients are then applied to estimate manufacturing and operational employment through 2047. A detailed explanation of the methodology is provided in Chapter 3.
- Case studies:** CEEW conducted a total of 22 semi-structured, in-depth interviews with a diverse set of stakeholders, including Managing Directors, Operations Managers, Depot Managers, OEM representatives, staff members (drivers, conductors, and maintenance personnel), as well as strategic leads from 4 CTUs, and 4 private companies. These interactions aimed to capture insights into the motivations, operational practices, infrastructure planning, and workforce management challenges related to bus electrification. To document the eight case studies, the CEEW team spent between 5 to 7 days at each site, engaging directly with stakeholders for detailed data collection.



Despite rapid e-bus growth, diesel buses hold 95% share of annual sales, underscoring the urgent need to overcome adoption barriers



Image: QCEW

2. India's bus market: Sales trends and future outlook

Buses in India account for approximately 40 per cent of road-based travel demand, measured in passenger kilometres travelled (TERI 2024). The Indian bus market, considered the third-largest in the world (MoRTH 2023), is projected to reach a value of USD 11.8 billion (INR 1.04 lakh crore) by 2026, with a CAGR of over 6.36 per cent for public buses operated by state transport undertakings (STUs) and 7.37 per cent for private buses (Grant Thornton Bharat 2024). The sector encompasses various use cases, including public, private, and institutional operations.



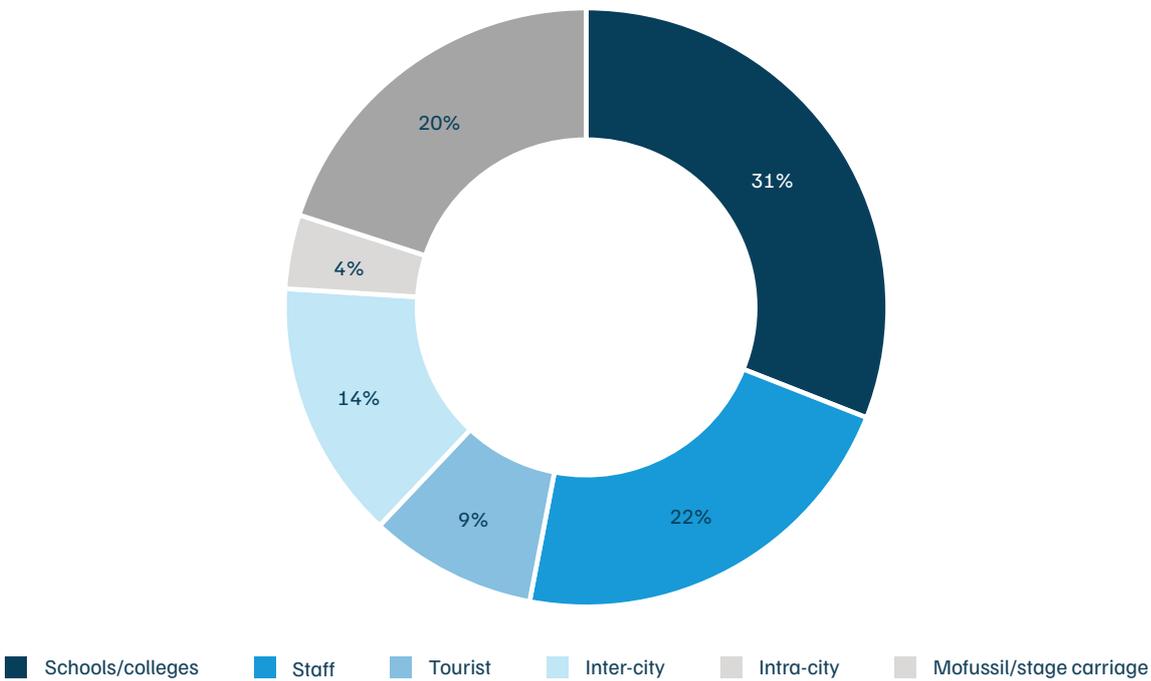
Box 1. Bus use cases

- **School/college buses:** These are vehicles of educational Institutions registered under the Societies Act, 1960. For identification, these buses shall be painted 'golden yellow'. For school identification, a colour band that is 150 mm \pm 10 mm wide shall be provided on both sides of the bus below the window level (MoRTH n.d.).
- **Staff buses:** Dedicated to employee transport, typically provided by companies or institutions.
- **Tourist buses:** Used for organised travel and sightseeing, often featuring comfort-oriented amenities.
- **Inter-city buses:** Connects different cities, catering to long-distance travel.
- **Intra-city buses:** Operates within a single city, serving urban commuters with frequent stops.
- **Mofussil buses:** Operates between towns and rural areas, serving semi-urban and village commuters.

Source: Authors' compilation



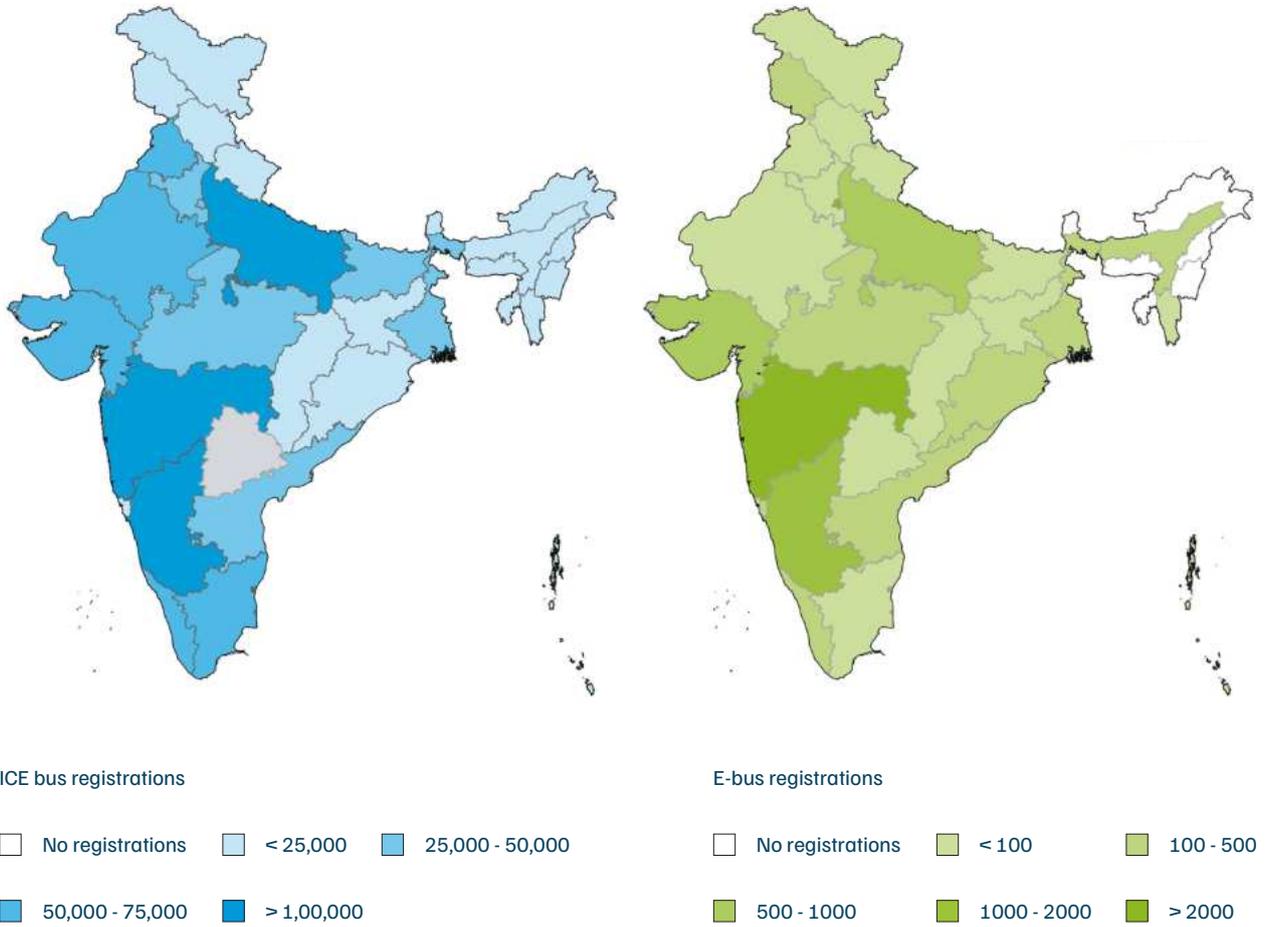
Figure 1. School/college buses, staff buses, and mofussil buses comprised nearly three-fourths of bus operations in 2023–24



Source: Authors' analysis using Indian Institute Of Technology–Madras Centre of Excellence - Zero emission trucks (IITM-CoE-ZET) data

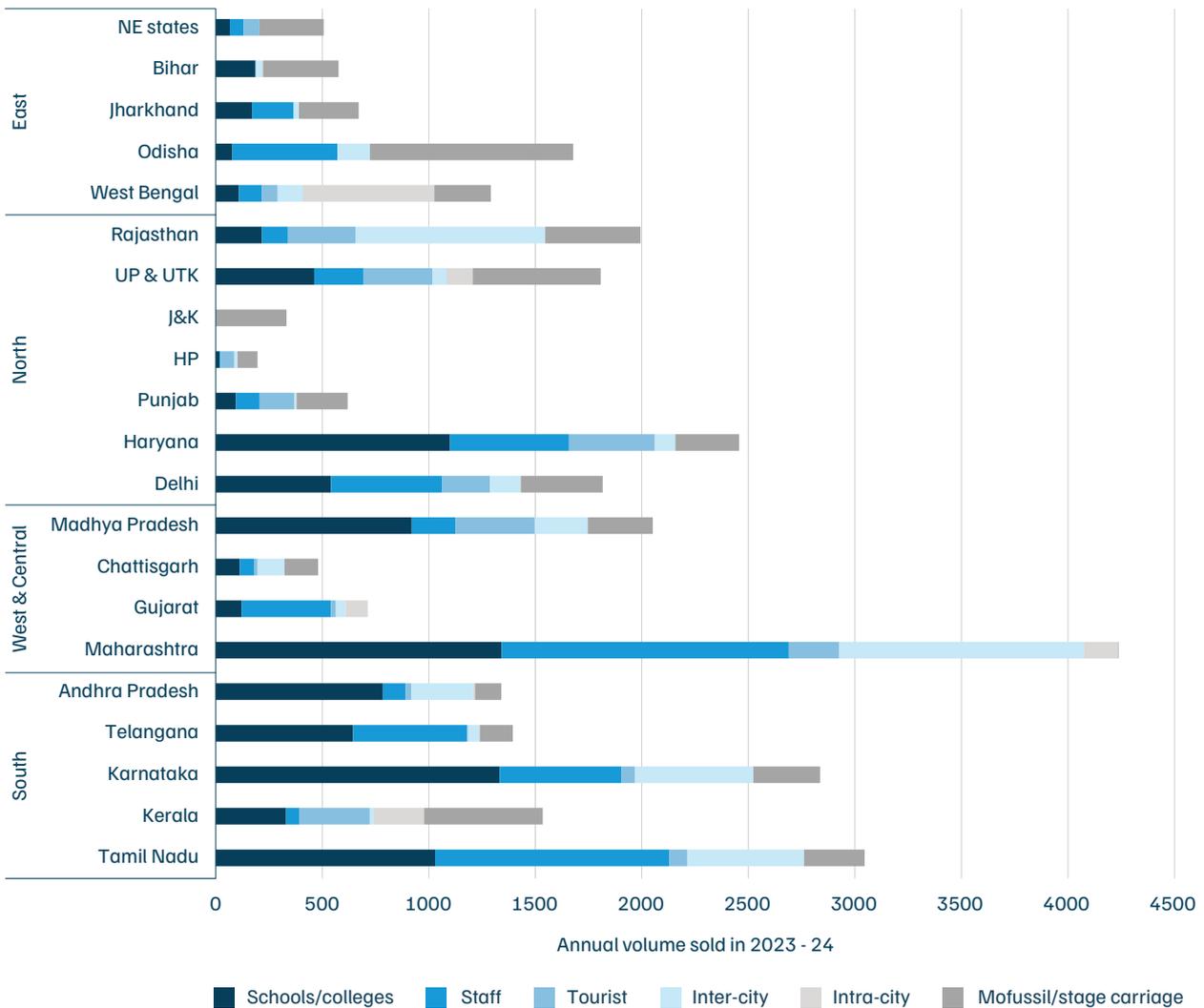
Sales data for 2023–24 (Figure 1) indicate that school/college buses remain the most common use case, followed by staff buses and mofussil/stage carriage buses. The data highlight geographic variations across states in terms of bus volumes (Figures 2 and 3). Around 52 per cent of all buses registered in 2023–24 were concentrated in six states: Maharashtra (13.4%), Tamil Nadu (9.6%), Karnataka (9%), Haryana (7.8%), Madhya Pradesh (6.5%) and Rajasthan (6.3%). Approximately 60 per cent of school, college, and staff buses are registered in the South and Central-West regions of the country, with Maharashtra, Tamil Nadu, Karnataka, and Haryana being the leading states. In contrast, nearly 75 per cent of all tourist buses are concentrated in North and Central-West India, with Haryana, Uttar Pradesh, Rajasthan, and Madhya Pradesh emerging as the dominant states in this segment.

Figure 2. Maharashtra records the highest medium-and heavy-duty ICE and e-bus registrations in India (2001–2024)



Source: Authors' analysis using Vahan dashboard (n.d.) data

Figure 3. High variations in bus volume and use cases are observed across states and regions in India



Source: Authors' analysis using Indian Institute of Technology Madras - Centre of Excellence - Zero Emission Trucks (IITM-CoE-ZET) data received during primary survey

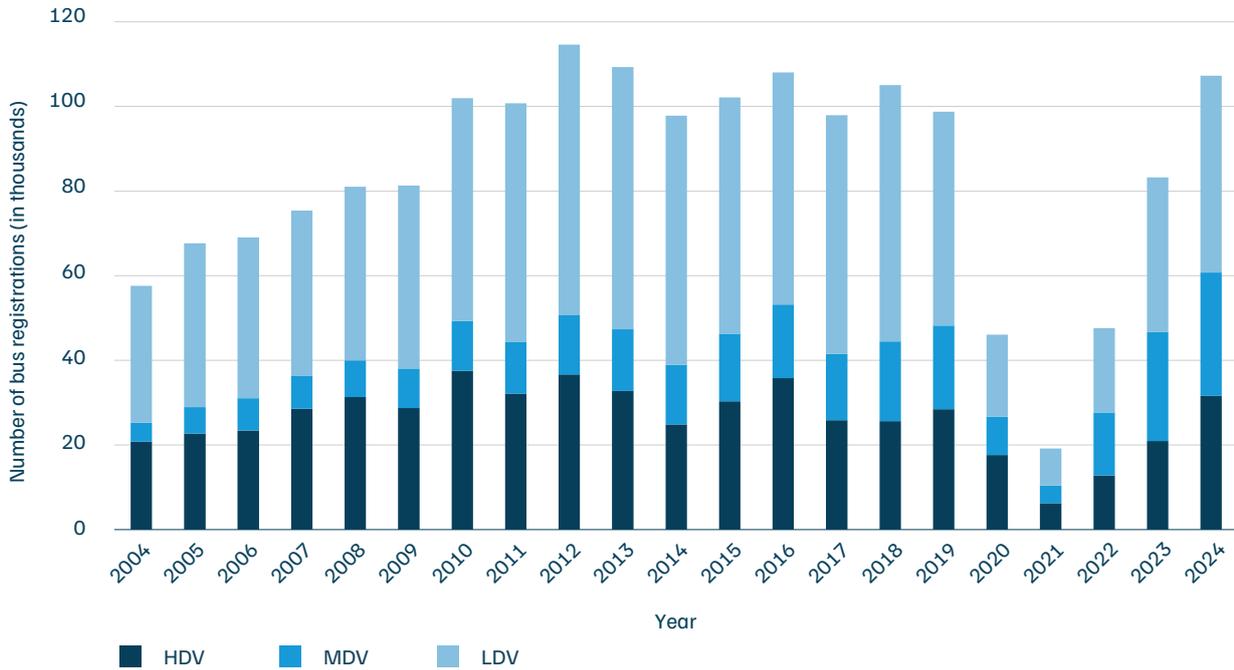
India's bus market, marked by dynamic changes in technology, policy, and environmental initiatives, is transforming. Our analysis of historical registration data for light⁶ (LDV), medium⁷ (MDV), and heavy⁸ (HDV) duty buses reveals that the market is dominated by diesel vehicles. However, over the past 15 years, the bus market has experienced a clean-tech transition, with annual e-bus sales rising from fewer than 5 units before 2015 to 4,025 units sold in 2024 (Figure 5).

6. LDV: Light duty vehicles are motor vehicles with a gross weight of less than 7.5 ton.

7. MDV: Medium duty vehicles are motor vehicles with a gross weight between 7.5 to 11 ton.

8. HDV: Heavy duty vehicles are motor vehicles with a gross weight of more than 11 ton.

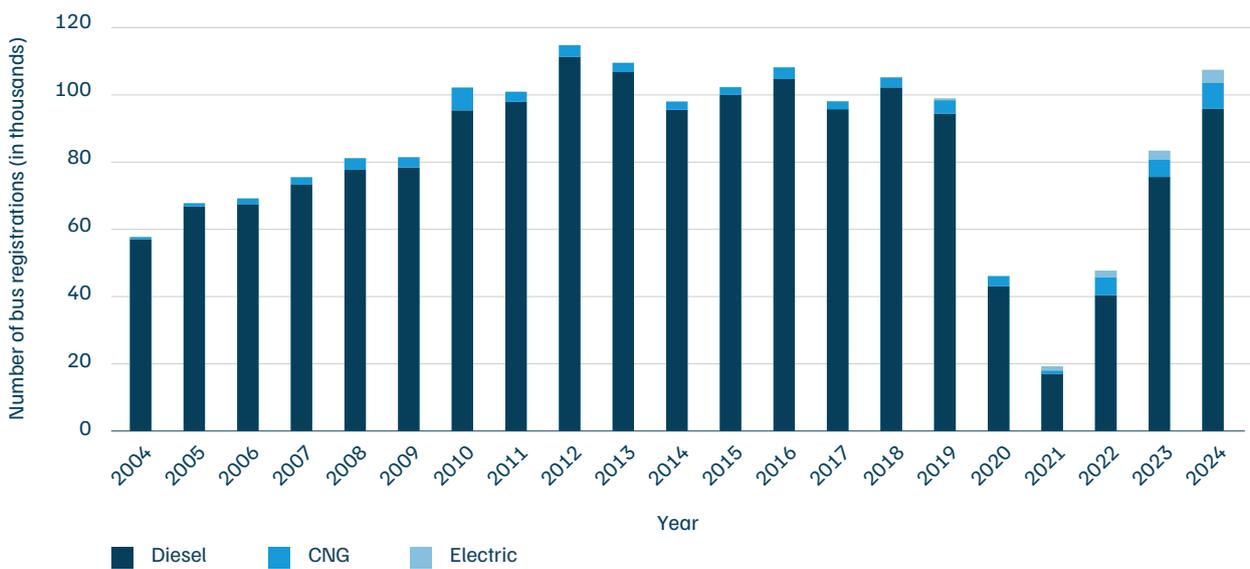
Figure 4. The proportionate market of LDV, MDV and HDV buses has continuously increased post-COVID



Source: Authors' analysis using Vahan dashboard (n.d.) data

India has been a market of about 0.1 million (one lakh) new buses every year since 2010. The bus market suffered notably during COVID-19, between the years 2020 and 2022, but bounced back in 2024 (Figure 5).

Figure 5. The bus market recovered fully in 2024 from the COVID impact, reaching one lakh registrations per year



Source: Authors' analysis using Vahan dashboard (n.d.) data

Figure 6. The number of original equipment manufacturers providing electric variants has rapidly increased since national e-bus schemes were announced post-COVID

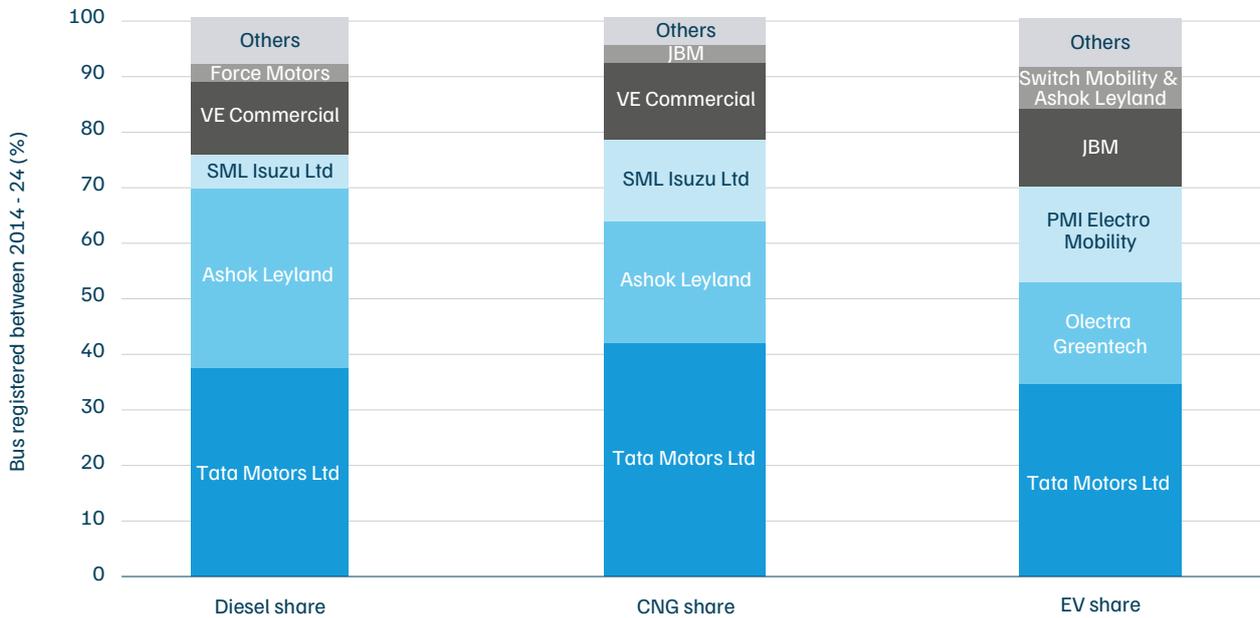


Source: Authors' analysis using Vahan dashboard (n.d.) data

Backed by the success of the government's 2021 *Product-linked Incentive (PLI)-Auto* scheme, by 2024, the number of bus makers (OEMs) producing e-buses surpassed those producing diesel buses for the first time (Figure 6). An analysis of bus registration data and companies highlights that traditional ICE bus manufacturers are shifting to e-bus manufacturing. Also, several newer OEMs are trying to gain e-bus market share.

A comparative analysis of the Indian bus market over the last 10 years (2014–2024) shows that there are around 0.85 million (8.56 lakh) diesel buses operational in India produced by more than 152 manufacturers. Conversely, the CNG bus market has experienced a fairly modest uptake, with approximately 40,000 units sold by 16 manufacturers. However, in contrast to their ICE counterparts, more e-bus makers are entering the market year-on-year (Figure 6). Our study indicates that the Indian bus market is fairly consolidated, with the top five companies dominating 91.3 per cent of registrations across the three fuel types (Figure 7). However, newer OEMs have managed to capture a significant market share (approximately 30 per cent) of e-bus demand.

Figure 7. Indian bus market is fairly consolidated, with top five companies dominating 91.3% of registrations across the three fuel types



Source: Authors' analysis using Vahan dashboard (n.d.) data

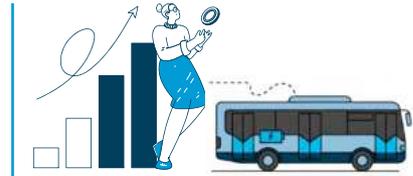
India has also emerged as the second-largest exporter of e-buses globally. Between March 2023 and February 2024, India shipped 1,529 e-buses, recording annual growth of 80 per cent despite a decline in February 2024 (Volza Grow Global 2024). Key destinations include Vietnam, the United States, Nigeria, and the UAE, reflecting India's expanding global footprint in the e-bus market.

2.1 The electric bus market in India

Government initiatives like the *National Electric Mobility Mission Plan (NEMMP)*, the *Faster Adoption and Manufacturing of Hybrid and Electric Vehicles (FAME)* schemes, the *PM-eBus Sewa* scheme, and state subsidies have led to the deployment of thousands of e-buses across India. Convergence Energy Services Limited (CESL), a green energy focused venture of The EESL Group owned by central public sector undertakings under the Ministry of Power, New and Renewable Energy, has established centralised bulk e-bus procurement tenders for cities and states, ensuring that manufacturers can secure medium-term supply orders that provide exact bus specifications through aggregation, removing the need for individual contract negotiations with cities. In turn, cities enjoy lower costs due to economies of scale and collective negotiation powers, which aid in streamlining business models, contract clauses, and performance benchmarks. This has helped reduce public investments for STUs procuring e-bus assets, increased the pace of the EV transition at the city and state level, and enabled quicker investment recovery for OEMs.

Electric buses reduce operating costs by 31 per cent and 18 per cent, respectively, when compared to traditional diesel and CNG buses (CESL 2022). As the share of e-buses increases in fleets, CTUs' reliance on fossil fuels has reduced. E-buses are thus helping reduce emissions from bus fleets, enhancing air quality in urban areas.

Many Indian cities have started making e-buses as part of their fleet. Delhi, the second-most populous megacity in the world (UN Report 2018), has emerged as a leader in e-bus adoption, with approximately 2,000 e-buses in operation in December 2024, and an additional 1,000 e-buses planned to be made operational by March 2025 (*Hindustan Times* 2025). Under the *Grand Challenge Phase-II* tender, the Government of the National Capital Territory of Delhi (GNCTD) plans to procure 6,380 more e-buses, increasing their share in Delhi's fleet from just 2 per cent in 2022 to an ambitious 70 per cent by 2025 (DDC-D et al. 2022). Beyond Delhi, several Indian cities and eco-sensitive zones have made e-buses part of their tourism plan.



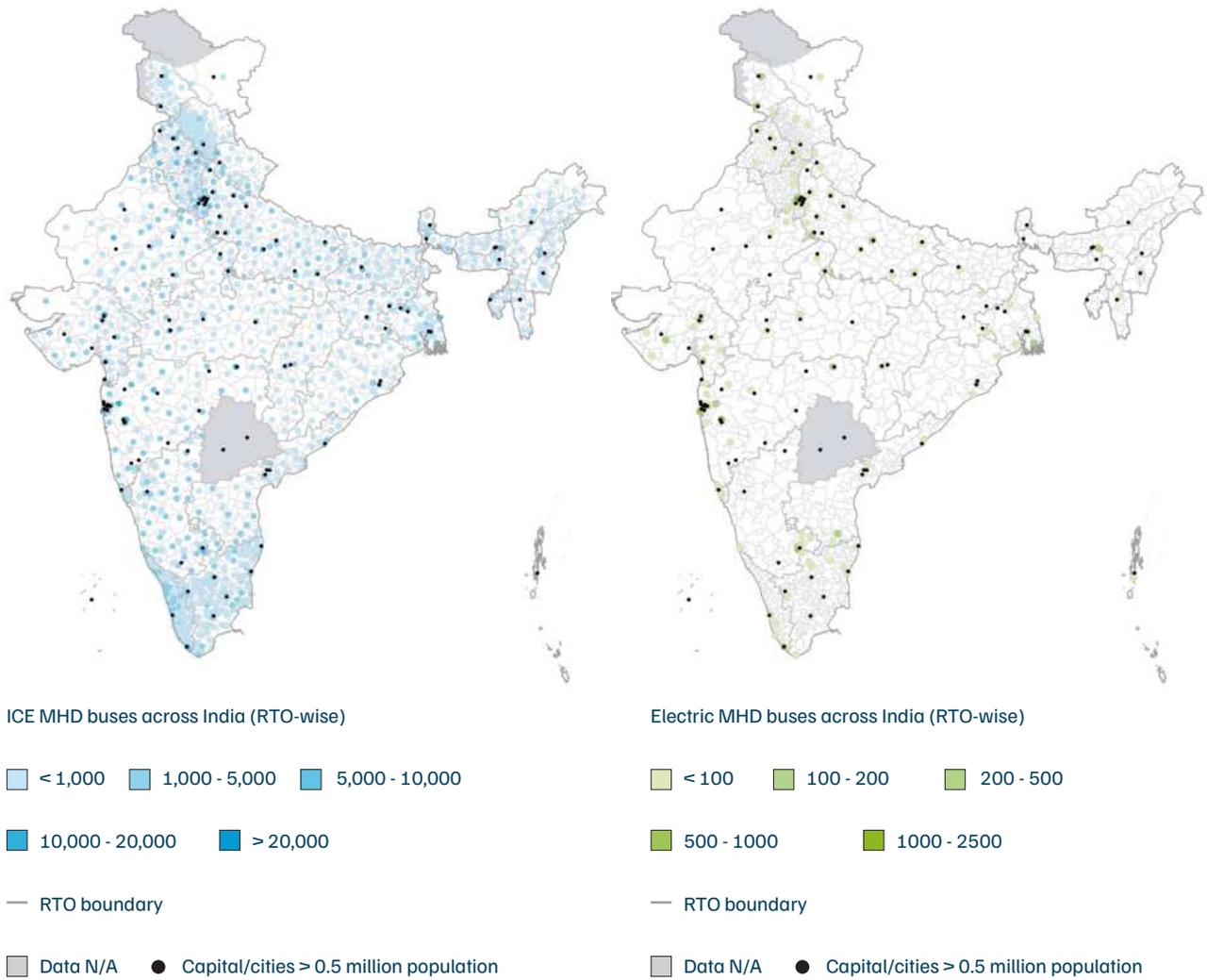
The number of OEMs offering electric bus variants has nearly tripled since the launch of national e-bus schemes post-COVID

- **Kevadia, Gujarat**—India's first **electric vehicle-only zone** (Economic Diplomacy Division 2021) **deployed 30 e-buses in March 2024** through a collaboration between CESL and the Statue of Unity Area Development and Tourism Governance Authority (SOUADTGA), ensuring a zero-emission transport network around the Statue of Unity.
- At **Bhagirathi Eco-Sensitive Zone**, the tourism department has **restricted petrol/diesel vehicles in the region** and allows **e-buses as an alternate means of transport** (BRVDA n.d.).
- **To preserve the eco-sensitive areas of Rohtang Pass**, the National Green Tribunal (NGT) banned diesel vehicles and passed an environmental tax order that levied an INR 1,000 charge on petrol vehicles and INR 2,500 on diesel vehicles entering the tourist area. This made Himachal Pradesh the **first hill state to adopt e-buses** for facilitating sustainable transport in high-altitude regions (GGGI and CSTEP 2016).
- **Pilgrims and tourist destinations** like **Ayodhya, Prayagraj, and Ajanta Caves** have **integrated e-buses into their tourist plans** to enhance sustainable mobility for visitors while reducing the carbon footprint of mass transport.

These efforts across multiple geographical regions and use cases have strengthened confidence among state and local governments in adopting e-bus fleets to support their decarbonisation efforts.

An analysis of e-bus registrations (Figure 8) highlights the geographical variation across the country. Bus registration data from 2014–2024 at the regional transportation office (RTO) level highlights that e-bus adoption remains concentrated in a few state capitals and large urban agglomerations in Uttar Pradesh, Maharashtra, Gujarat, Delhi, and Himachal Pradesh. Except for Assam and Mizoram, other states in the Northeast are yet to procure e-buses. We find that most of the other states have fewer than 500 e-buses.

Figure 8. E-bus penetration remains consolidated across urban hubs (2014–2024)



Source: Authors' analysis using Vahan dashboard (n.d.) data

Table 1. Delhi's regional transport office (DL51) recorded the highest ICE bus registrations between 2014 and 2024, followed by Pune (MH12) and Gandhinagar (GJ18)

S. no.	State	RTO	RTO Code	ICE bus registrations
1	Delhi	Delhi	DL51	16,863
2	Maharashtra	Pune	MH12	12,411
3	Gujarat	Gandhinagar	GJ18	11,473
4	Karnataka	Bengaluru Central	KA1	8,658
5	Tamil Nadu	Chennai Central	TN1	7,829

Source: Authors' analysis using Vahan dashboard (n.d.) data

Table 2. Delhi's regional transport office (DL00) recorded the highest e-bus registrations between 2014 and 2024, followed by Bengaluru South (KA5) and Pune (MH12)

S. no.	State	RTO	RTO Code	E-bus registrations
1	Delhi	Delhi	DL00	1481
2	Karnataka	Bengaluru South	KA05	545
3	Maharashtra	Pune	MH12	527
4	Maharashtra	Mumbai		368
5	Maharashtra	Thane	MH04	313

Source: Authors' analysis using Vahan dashboard (n.d.) data

CEEW's TFFM projects vehicle sales, refuelling infrastructure, and fuel demand in the transport sector till 2050. It forecasts the growth of vehicle stock using the Gompertz function, informed by local GDP, population growth, and historical vehicle sales trends (2001–2023). The model allocates fuel-technology decisions for new vehicles sold based on the total cost of ownership⁹ (TCO), refuelling infrastructure constraints, and overall sentiments/perceptions obtained from Delphi; details can be found in Annexure 1. The model uses vehicle sales trends from 2013 to 2019, backed by comprehensive discussions with industry leaders, government stakeholders, and specialists, to ensure consistency with real-world situations and industry plans. We adopt the vehicle sales projections and fuel technology choice decisions for the next 20 years from the TFFM model.

The TFFM findings project that the on-road bus stock across the country will increase to approximately 3.34 million (33.4 lakh) buses by 2047. Diesel buses will likely continue to lead the market with around 2.87 million (28.7 lakh) buses, representing 71 per cent of the overall bus stock. In this timeframe, electric and hydrogen fuel cell electric buses (HFCEVs) may collectively account for a significant 29 per cent share.

Our analysis predicts a projected CAGR of around 10.7 per cent for the e-bus market between 2025 and 2047, indicating that India's e-bus market is poised for rapid expansion. Beyond the environmental benefits, e-buses will also create new job opportunities in the market.

9. The total cost of ownership of a vehicle is defined as the overall cost of operation of the vehicle, including the capital, fuel, and manpower cost spent over the course of the vehicle's life.



Image: Industry

3. Jobs in bus sector by 2047

Buses remain the only crucial means of affordable mobility for several million households in India. E-buses are poised to not only alter the market landscape but also reset public transport perceptions due to their comfort, attractiveness, and popularity. We explore the potential for manufacturing and operational job creation in the sector and its capacity to provide livelihoods across India.

The Ministry of Skill Development and Entrepreneurship estimates that the EV industry could generate 10 million (1 crore) direct jobs and 50 million (5 crore) indirect jobs by 2030 (Economic Survey 2023). These jobs span various domains, including the supply chain, operations, analytics, design, and research and development.

As per the *Economic Survey 2025*, India's automobile industry recorded a 12.5 per cent domestic sales growth in FY24, with the passenger vehicle (bus) segment growing 4.2 per cent between April and November 2024.

Our TTFM estimates that there were 1.1 million (11 lakh) on-road buses in 2024, which will rise to 1.65 million (16.5 lakh) buses and 3.3 million (33 lakh) buses by 2030 and 2047, respectively. Using these figures, we forecast pre-procurement (manufacturing) and post-procurement (operational) jobs associated with bus operations. It is crucial to note that the exercise uses domestic bus stock demand to assess the jobs generated; hence, this study does not consider manufacturing jobs generated due to the export of buses produced domestically or those lost due to the import of buses.

3.1 Estimated jobs in manufacturing

The bus manufacturing sector in India comprises light passenger vehicles (LPVs), medium passenger vehicles (MPVs), and heavy passenger vehicles (HPVs). Using CEEW's TTFM annual bus fleet registration forecasts, we estimate the potential increase in manufacturing jobs (Table 4) using the coefficients presented in Table 3. Job coefficients from the European Union (EU) have been used, as the number of buses sold in the EU market is comparable to that in India.

Table 3. Job coefficient per unit for bus manufacturing

Bus manufacturing coefficient (jobs per unit) ¹⁰					
Fuel type	Supplier	OEM	ZEV infra	MHDV utility (energy + fuel)	Total manufacturing jobs (per bus)
e-bus	0.60	0.52	0.04	0.22	1.39
ICE bus	0.68	0.71	-	0.25	1.64

Source: Boston Consulting Group. 2023. *Impact Assessment of the Transition to Zero-Emission Trucks in Europe. Transport and Environment*

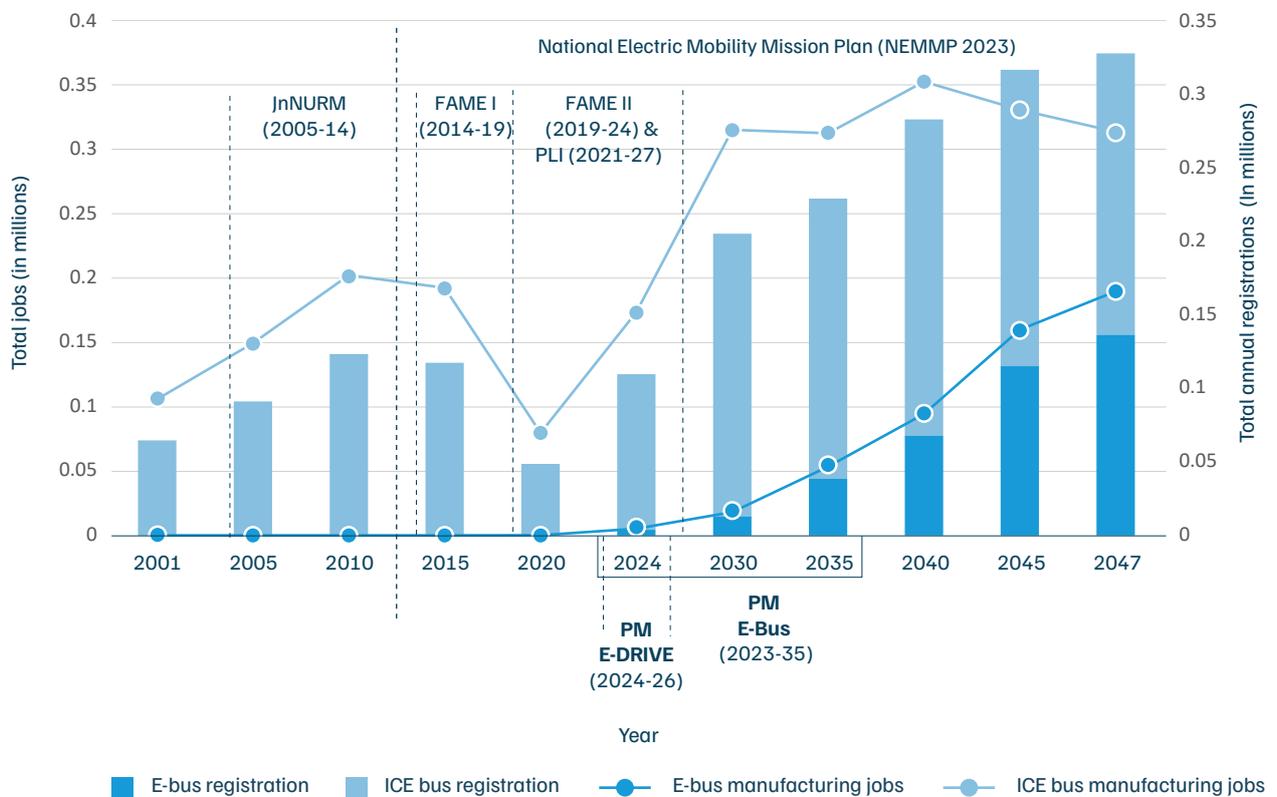
Table 4. Estimated manufacturing jobs till 2047 (in millions)

Year	New registrations			Manufacturing jobs		
	E-bus	ICE bus	Total	E-bus jobs	ICE bus jobs	Total jobs
2030	0.01	0.19	0.21	0.02	0.32	0.34
2040	0.07	0.22	0.28	0.09	0.35	0.45
2047	0.14	0.19	0.33	0.19	0.32	0.51

Source: Authors' analysis

10. ZEV—Zero-Emission Vehicle; MHDV—Medium- and Heavy-Duty Vehicle.

Figure 9. E-bus manufacturing jobs are expected to have steady growth while ICE bus manufacturing will stagnate

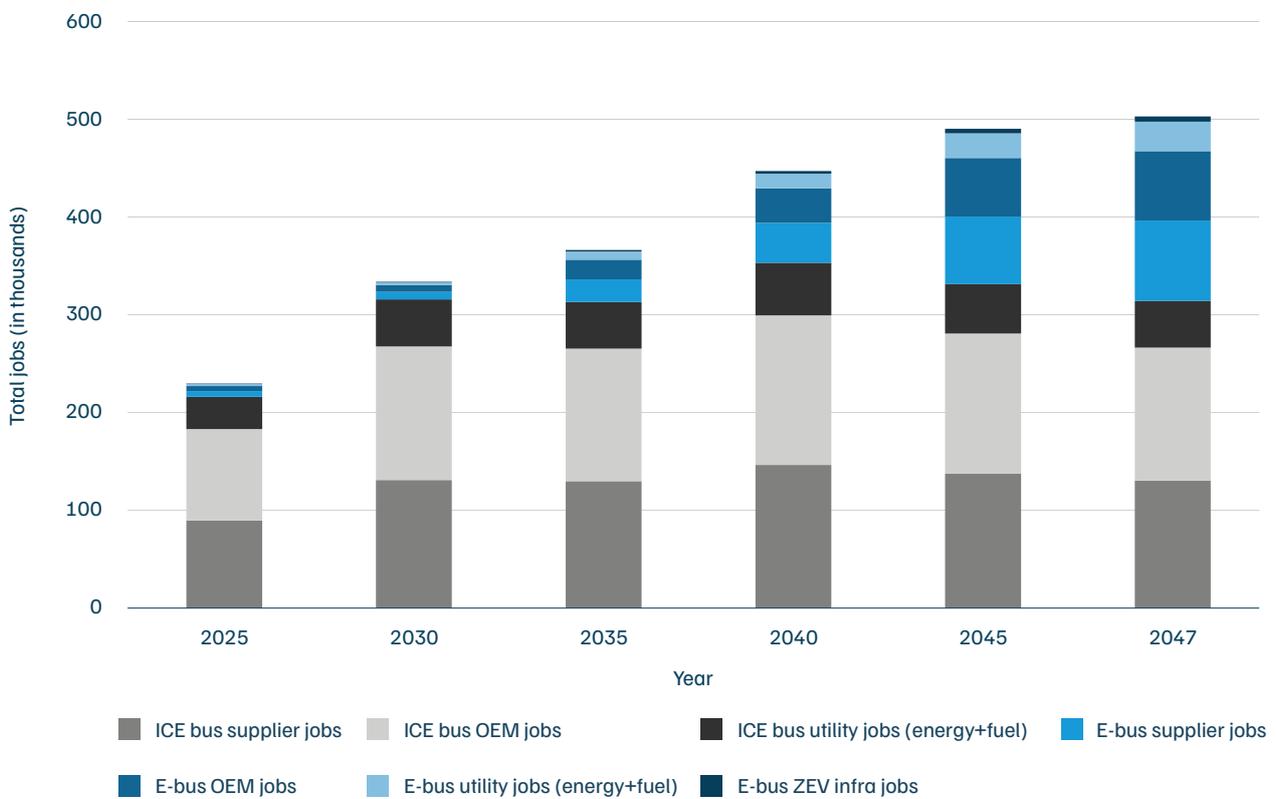


Source: Authors' analysis

Based on the TFFM bus stock, we estimate that the bus sector will generate 0.34 million (3.4 lakh) manufacturing jobs by 2030, and 0.45 million (4.5 lakh) and 0.51 million (5.1 lakh) manufacturing jobs by 2040 and 2047, respectively. The study estimates that e-bus adoption will create approximately 0.02 million (0.2 lakh) manufacturing jobs by 2030, 0.09 million (0.9 lakh) by 2040, and 0.19 million (19 lakh) manufacturing jobs by 2047. This growth underscores the significant employment potential of the e-bus sector, contributing to sustainable development and the clean energy transition. Our analysis shows that the demand for buses in the domestic market will rise rapidly. Annual bus registrations are projected to increase from approximately 0.1 million (1 lakh) in 2024 to around 0.3 million (3 lakh) by 2047. Between 2025 and 2030, ICE buses will see a steep increase in demand (Figure 9), due to their lower capital costs and lower TCO for widespread use cases, such as school and staff buses, where bus utilisation is lower than 200 km a day. Although ICE bus registrations are expected to peak in 2040, the demand for e-buses will continue to show sustained growth till 2047, backed by the reducing TCO and improving access to charging infrastructure.

According to the literature, in a mature zero-emission truck market, manufacturing jobs will be distributed as follows: suppliers (41 per cent), OEMs (42 per cent), zero-emission vehicle (ZEV) infrastructure (2 per cent), and medium- and heavy-duty vehicle (MHDV) related utilities (15 per cent) (Figure 10). The supply chain is expected to account for a significant share of the jobs created due to the extensive workforce requirements of component manufacturing, including battery cells, power electronics, and drive systems. OEM jobs include those related to vehicle assembly, integration, and quality control. Jobs in the ZEV infrastructure segment will be critical for charging network deployment, and employment in MHDV-related utilities are looking to expand the supply of renewable energy (BCG 2023).

Figure 10. E-bus manufacturing jobs are projected to grow at 13.3% CAGR by 2047, driven by rising supplier and bus OEM jobs



Source: Authors' analysis

According to our research, jobs in the e-bus supply chain are expected to rise significantly—from approximately 6,000 in 2025 to 82,000 by 2047. In contrast, employment in the ICE bus supply chain is projected to grow at a steadier pace, from about 90,000 in 2025 to nearly 130,000 by 2047, driven by continued demand for new buses. However, the distribution of employment in utility sectors is expected to change at similar pace for both the fuel type over the same period.

3.2 Estimated jobs in operations

Operational or post-procurement roles within the bus sector include the jobs of drivers, conductors, administration staff, supervisors, and cleaning and maintenance personnel. We identified the operational job coefficient from the staff-to-bus ratio that was identified for ICE and e-buses using primary data collection for the various job heads and use cases, as highlighted in Table 5. To estimate operational jobs, we calculate the weighted proportion distribution of different bus use cases to the operational coefficient for ICE and e-buses (Table 6).

Table 5. Staff-to-bus ratio for ICE buses and e-buses across various use cases

Use case	Inter-city		Intra-city		Staff		School*		Tourist*		Mofussil*	
	e-bus	ICE bus	e-bus	ICE bus	e-bus	ICE bus	e-bus	ICE bus	e-bus	ICE bus	e-bus	ICE bus
Drivers	2.67	2.59	1.88	1.7	1.2	1.04	1.11		1.25		1.875	
Conductors	1.58	1.68	1.27	1.2	-	0.04	0.96		0.02		1.875	
Workshop & maintenance staff	1.03	0.60	0.37	0.3	0.05	0.05	0		0.07		0.0875	
Bus station staff, inspectors, supervisors, etc	0.28	0.10	0.50	0.6	0.15	0.01	0.06		0.13		0	
Admin staff	0.10	0.17	0.14	0.2	0.2	0.08	0.08		0.12		0.225	
Total	5.65	5.14	4.16	4.00	1.60	1.22	2.21		1.59		4.06	

Source: Authors' analysis

Note: *Staff-to-bus ratio for e-buses is assumed to be the same as ICE buses due to lack of available data.

Table 6. Use-case-wise job coefficients, utilisation, and estimated daily passenger per bus

Bus use case	Share of bus use case (%)	Weighted operational jobs coefficient for the number of people required per bus		Bus utilisation (km/day)	Est. passenger per bus per day
		ICE bus	e-bus		
Schools/ colleges	31	0.67	0.67*	89	80
Staff	22	0.26	0.35	106	80
Tourist	9	0.14	0.14*	249	80
Inter-city	15	0.75	0.82	450	100
Intra-city	4	0.16	0.17	130 -170	300
Mofussil/ stage carriage	20	0.84	0.85*	120	300

Source: Authors' compilation (primary data; CoE-ZET IITM data)

Note: *coefficients were assumed due to data unavailability.

We find that a total of 2.99 persons are required to operate an e-bus, while 2.82 persons are required per ICE bus. Thus, the job intensity of e-buses is greater than that of ICE owing to the need for charging staff.

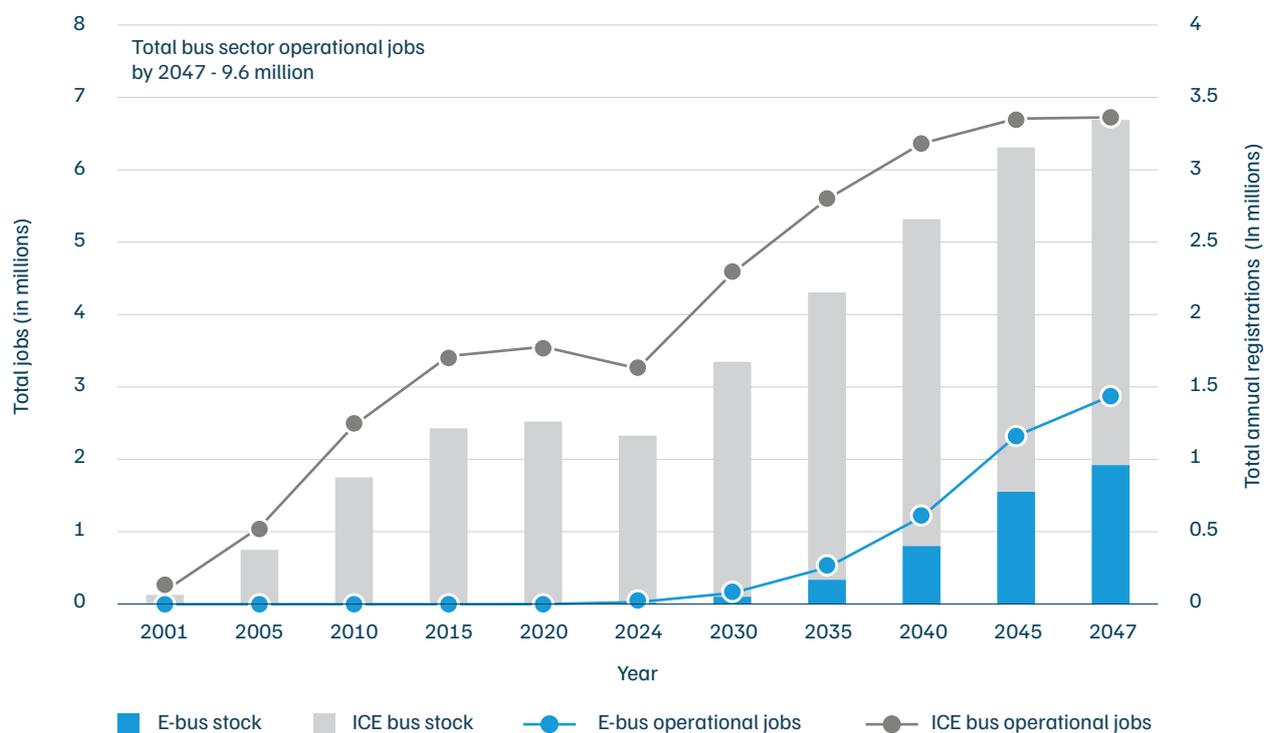
The TFFM model estimates the year-on-year (YoY) growth in new registrations and the on-road bus stock till 2047. The on-road bus stock is predicted to be 1.67 million (16.7 lakh), 2.67 million (26.7 lakh), and 3.34 million (33.4 lakh) by 2030, 2040, and 2047, respectively. The proportion of e-buses in the total bus stock is estimated to be 3 per cent, 15 per cent, and 29 per cent by 2030, 2040, and 2047, respectively. The aggregated weighted proportion of various operational coefficients in the various use cases is used to estimate the growth in operational jobs in the ICE and e-bus segments for the years 2030, 2040, and 2047 (Table 7). The bus sector is estimated to generate 9.6 million operational jobs by 2047 (Table 7).

Table 7. Estimated operational jobs by 2047 in the Indian bus sector (in millions)

Year	On-road bus stock			Operational jobs		
	E-bus	ICE bus	Total	E-bus jobs	ICE bus jobs	Total jobs
2030	0.05	1.6	1.6	0.2	4.6	4.7
2040	0.4	2.2	2.6	1.2	6.4	7.6
2047	0.9	2.3	3.3	2.9	6.7	9.6

Source: Authors' analysis

Figure 11. E-bus operations jobs are expected to have steady growth while that of ICE bus will stagnate



Source: Authors' analysis

3.3 Overall estimated jobs

The study estimates that the bus sector (e-bus and ICE bus) has the potential to generate gross employment (operational and manufacturing jobs) of 5.14 million (51.4 lakh), 8.4 million (84 lakhs), and 10.11 million (1.01 crore) jobs by 2030, 2040, and 2047, respectively (Table 8). Assuming a projected total population of 1.7 billion (approx. 170 crore) by 2047 (NAREDCO, Knight Frank 2023, 7–8) and an average household size of 4.1 (compared to the current average of 4.2), the bus sector is expected to support the livelihoods of approximately 2.3 per cent of India's future population.

Table 8. Overall estimated jobs by 2047 (in millions) in the bus sector

Year	E-bus			ICE bus			Total jobs in the bus sector
	Operational jobs	Manufacturing jobs	Total jobs in the e-bus sector	Operational jobs	Manufacturing jobs	Total jobs in the ICE bus sector	
2030	0.2	0.02	0.22	4.6	0.32	4.92	5.14
2040	1.2	0.09	1.29	6.4	0.35	6.75	8.04
2047	2.9	0.19	3.09	6.7	0.32	7.02	10.11

Source: Authors' analysis

However, under the BAU scenario, we find that the proportion of e-buses (including LDV, MDV, and HDV segments) in new sales (registrations) is expected to be only 6 per cent in 2030 and 42 per cent in 2047. This is significantly lower than NITI Aayog's policy target of 13–16 per cent e-bus penetration by FY30 (NITI Aayog et al., 2022). For sales to increase substantially over the next five years, it is crucial to identify and address the barriers to e-bus adoption. Thus, we study the early e-bus initiatives across the country.



Bus manufacturing and operations are expected to create 5.14 million and 10.11 million annual jobs by 2030 and 2047, respectively.



CEEW

4. Understanding India's e-bus initiatives

The transition to electric buses in India faces several challenges, spanning operational, financial, technological, and infrastructural domains. These include high capital costs, range and power concerns, lack of operational know-how, uncertainty around battery life, high land and infrastructure costs, limited availability of battery management data, and the absence of widely accessible public charging facilities (SAREP 2024; Sharma 2023; Khurana 2024).

Recognising these barriers, this study aims to document how different stakeholders across the country are attempting to address them. We identified a pool of 20 case studies where specific initiatives have been undertaken to tackle such challenges on the ground, or new avenues for e-bus deployment have been explored. From this pool, eight case studies were selected based on multiple criteria, including thematic diversity, geographic distribution, availability of reliable data for analysis, and necessary permissions from local stakeholders. Details of the stakeholders are provided in Annexure 2, while Table 9 outlines the thematic areas and case studies covered in this study.

Table 9. Selected case studies across India

Year	Thematic Area	Use case	Geography
2018	Battery swapping as an alternative to fixed charging	Intra-city bus rapid transit (BRT) pilot operations	Ahmedabad
2019	Operations management to address battery degradation	Intra-city operations under FAME I	Indore
2021	Depot planning to reduce dead kilometres	Intra-city BRT operations (electric)	Surat
2022	Alternate business models to cater to corporates	Private staff bus operations	Gandhinagar
2023	Gender inclusion in driving jobs	Private inter-city operations	Delhi NCR
2024	Rental model of operation	Intra-city stage carriage operations	Guwahati
2024	Retrofitting of buses to reduce the capital cost of e-buses	School buses, BRT operations	Pune
2025	Leveraging state-wide charging network	Occasional large pilgrimage and religious and festival demands	Prayagraj

Source: Authors' analysis

Deductive content analysis was employed to gain a deeper understanding of the subject. It systematically categorises and compares the dynamics across the two fuel technologies (ICE and e-buses) from the standpoint of various operation models and use cases (Bingham and Witkowsky 2022).

4.1 Fixed-cost operational model

Guwahati city, the largest city in the state of Assam, spreads over 216 sq km, making it the biggest metropolis in Northeast India. It has a population of one million people and is an educational, religious, administrative, cultural, and tourism hub, attracting various kinds of travellers. Buses are the major mode of public transport serving intra-city trips. Other shared modes, like hand-driven rickshaws, e-rickshaws, auto-rickshaws, TATA Magic cabs, and private taxis also cater to the city's travel demand.

Table 10. City statistics of Guwahati, Assam

Area	216 sq km
Population (Census 2011)	9,62,334
Popular modes of travel	Bus (ICE and electric), TATA Magic, and autorickshaws
The modal share of buses	30.2%

Source: Office of the Registrar General & Census Commissioner, India. Census of India 2011: Provisional Population Totals. New Delhi: Government of India, 2011 and Guwahati Master Plan 2025



CEEW team interacting with e-bus operators to understand the fixed-revenue model of operation in Guwahati.

In line with the country's net-zero emissions targets, the state government has announced ambitious plans to make Guwahati the first city in India with a green public transportation system by 2025 (Times of India 2024). The state plans to roll out electric and CNG buses, which are significantly less polluting than diesel buses. The Assam State Transport Corporation (ASTC) manages Guwahati's inter- and intra-city bus systems. As of January 2024, the intra-city fleet comprised 100 CNG buses, 15 e-buses procured under the FAME I scheme, and 200 e-buses funded by the Guwahati Smart City Project. The diesel buses are now used only for inter-city operations. With the addition of 56 new e-buses in January 2025, the city now has a total of 271 e-buses. Further, the city plans to add another 100 e-buses to its fleet by 2026 under the *PM e-Bus Sewa* scheme.

Table 11. Bus operation specifications of intra-city buses in Guwahati

Fleet type	CNG buses	E-buses
Area of operation	Intra-city	Intra-city
Year of operation	2023	2019 (15 e-buses) and 2024 (200 e-buses)
Fleet size	100	15 (FAME I) + 200 (<i>Smart Cities</i>)
Number of routes	7	12
Route length (min–max)	154 km (9–29 km)	409 km (9–55 km)
Age of fleet (in years)	2	1
Number of depots	1 (ISBT)	2 (ISBT and Rupnagar)
Number of chargers	-	31
Manpower total	-	600
Gender ratio (Others:Female:Male)	-	0:13:587
Number of drivers	-	260
Experience requirement	-	> 3 years
Salary of drivers (in INR)	-	INR 17,500
Number of conductors	-	260
Maintenance staff	-	27
Utilisation per bus per day	132 km	138 km
Avg. monthly fuel/power consumption	55 MT of CNG	~ 1 million (10 lakh) units
Cost of energy (INR per km)	31.7	12.2
Unit cost of power (INR per kWh)	-	8.56

Source: Assam State Transport Corporations, RB enterprises and Multitech Engineering

Table 12. Bus fleet specifications of intra-city buses in Guwahati

ASTC buses (Intra-city)	CNG buses	FAME 1 e-buses	TATA e-buses	Olectra e-buses
Fleet size	100	15	100	100
Year of procurement	2023	2019	2024	2024
Age of fleet (in years)	2	5	1	1
Operational fleet size (2024)	40	6	100	100
Operated by	ASTC		RB enterprises	Multitech
Drivers employed by			RB enterprises	Multitech
Conductors employed by			RB enterprises	Multitech
Maintained by			TATA (under 5 years AMC)	Olectra (under 5 years AMC)

Source: Assam State Transport Corporations, RB enterprises and Multitech Engineering

Unpacking the fixed-cost operation model

E-buses remain cost-prohibitive due to their high capital cost – they are over two - four times more expensive than diesel buses. The ‘gross cost contract model¹¹’ of e-bus operations has been widely practised across cities since *the Grand Challenge*, an initiative led by CESL that aggregated demand for e-buses supported under the government’s FAME-II scheme. The model helps convert the capital cost of e-buses into a predictable operational cost, as shown in the case of Surat. However, ASTC’s e-bus fleet operations in Guwahati use a distinctive model that prioritises efficiency and economic viability. **By implementing a fixed-revenue structure, ASTC ensures profitability for itself, including third-party operators.** Guwahati was able to implement this model as the **e-buses were procured using the Guwahati Smart City Fund**, eliminating capital costs concerns for ASTC. The operators pay fixed standing and running charges to the ASTC, which guarantees a stable income of around INR 7.5 million (INR 75 lakh) per month. This model **enables the ASTC to avoid the complexities associated with e-bus operations.** In contrast, ASTC owns and operates its CNG buses, incurring revenue losses in their operation.

11. In the Gross cost contract (GCC) model, the operator procure the e-buses as well as implement the charging infrastructure, which saves state transport undertakings (STUs) from making the initial capital investment. In exchange, the operator is paid based on the number of kilometres the buses are operated (ITDP 2022). In GCC, the public agency assumes the risk as it retains the responsibility of collecting fare revenue and uses it to pay the operators (WRI 2021).



Image: Anannya Jha/CEEW

CEEW team conducting semi-structured interviews with e-bus drivers in Guwahati to understand bus operations.

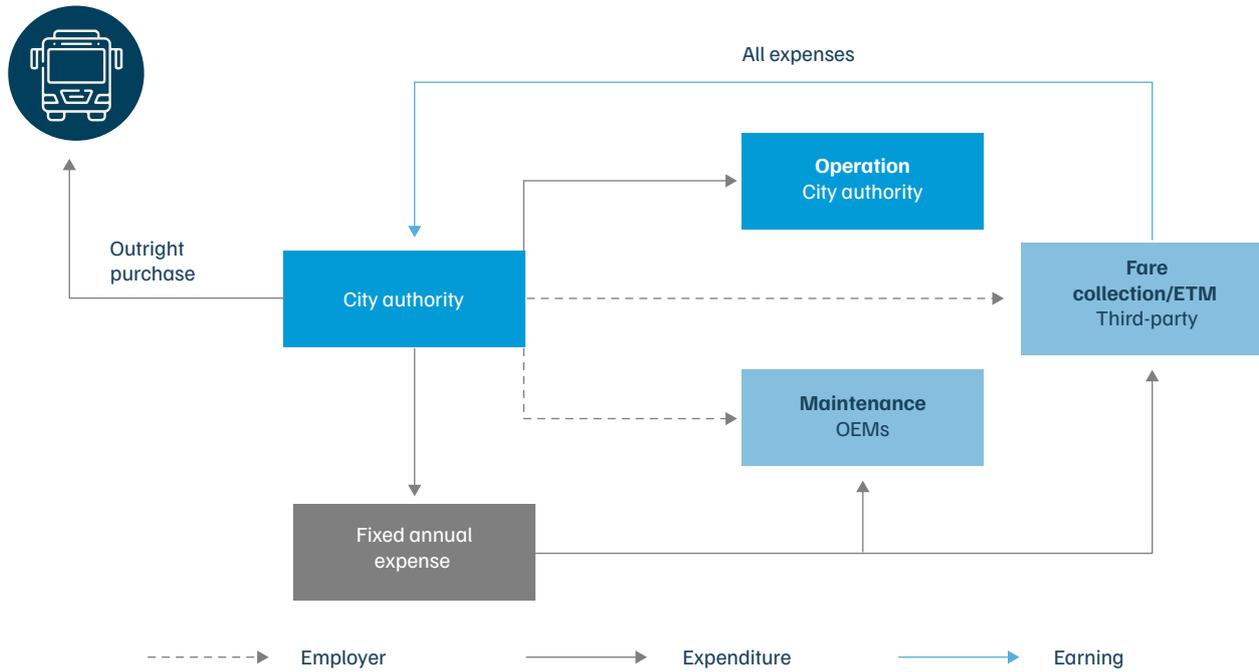
As per the contractual agreement, the operators are responsible for daily operations, staffing, and energy costs, while maintenance is covered under a five-year annual maintenance contract (AMC) with the OEMs. Our interviews with the operators, highlight that the drivers and conductors are given revenue targets based on route length and ridership to maximise operational efficiency. Ticket sales are logged at the end of each shift using electronic ticketing machines (ETMs). Operators are further incentivised to boost ridership and operational efficiencies through a revenue-sharing model, allowing them to retain any fare collected beyond the set target; however, failure to meet these targets will lead to a salary reduction. As the system motivates them to maximise ridership and maintain high service quality, buses are operated effectively, and users benefit from reliable and comfortable services, further boosting ridership. It is worth noting that the routes and fare is decided by ASTC while the scheduling is managed by the operators. However, having fixed revenue targets leads to unticketed travel – any revenue collected beyond the fixed target is retained by drivers and conductors, incentivising them to operate additional trips and extend their driving hours – as the fare collected during these extra trips often goes unrecorded, giving rise to discrepancies between actual and recorded ridership (Choudhury 2025).

The fixed-revenue model presents a balanced approach to ensuring operational consistency, minimising financial risks for all parties, and supporting Guwahati's green and sustainable transport system vision. The model can serve as a case example for enhancing contracts and operational efficiency.

Figures 12, 13, and 14 show the typical operational models of bus operations: the outright purchase model¹², the net cost contract (NCC) model¹³, and the gross cost contract (GCC) model, respectively. For comparison, the operational model of buses in Guwahati is shown in Figure 15.

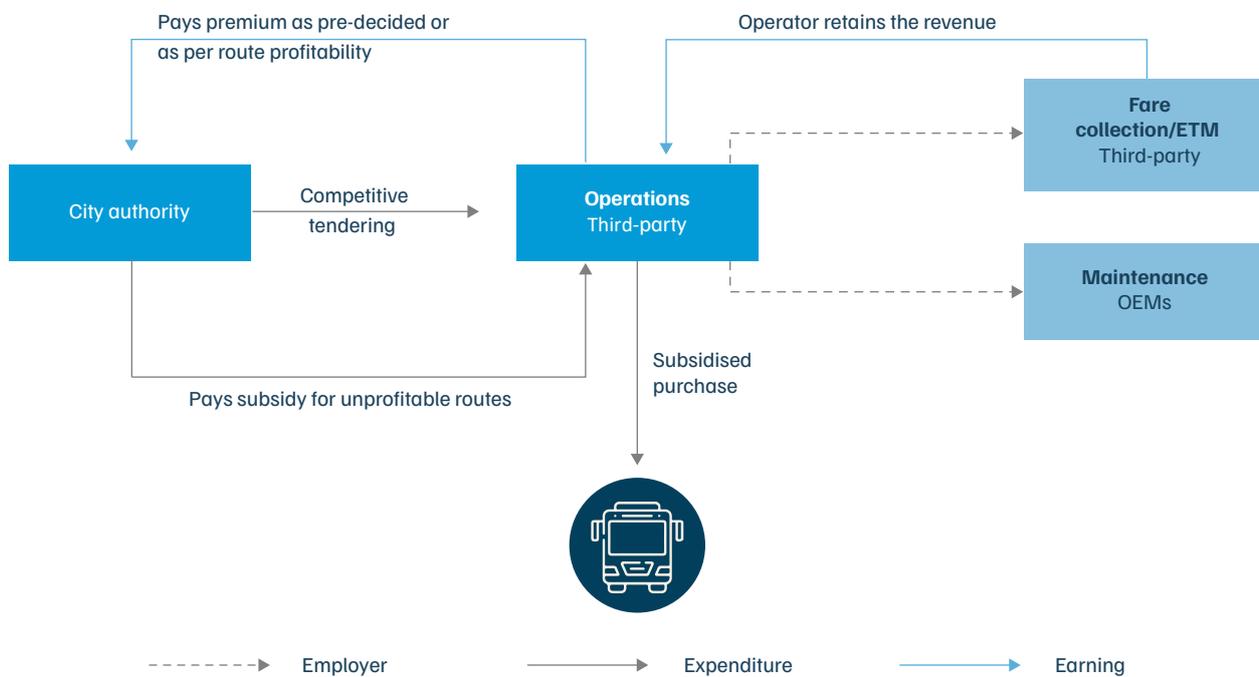
12. In Outright purchase model, the public transport agency buys buses directly from the manufacturer and takes full ownership of the fleet and are responsible for all operations and maintenance.
13. In net cost contract model, the operator provides the service for a specified period and retains all revenue. The authority pays a subsidy to the operator if the bus services in an area are unprofitable. If the services are profitable, the authority pays the operator a royalty. In this model, the risk is borne by the private operators as they are responsible for collecting fare and using it to cover costs involved in bus O&M (WRI 2021).

Figure 12. Typical outright purchase model



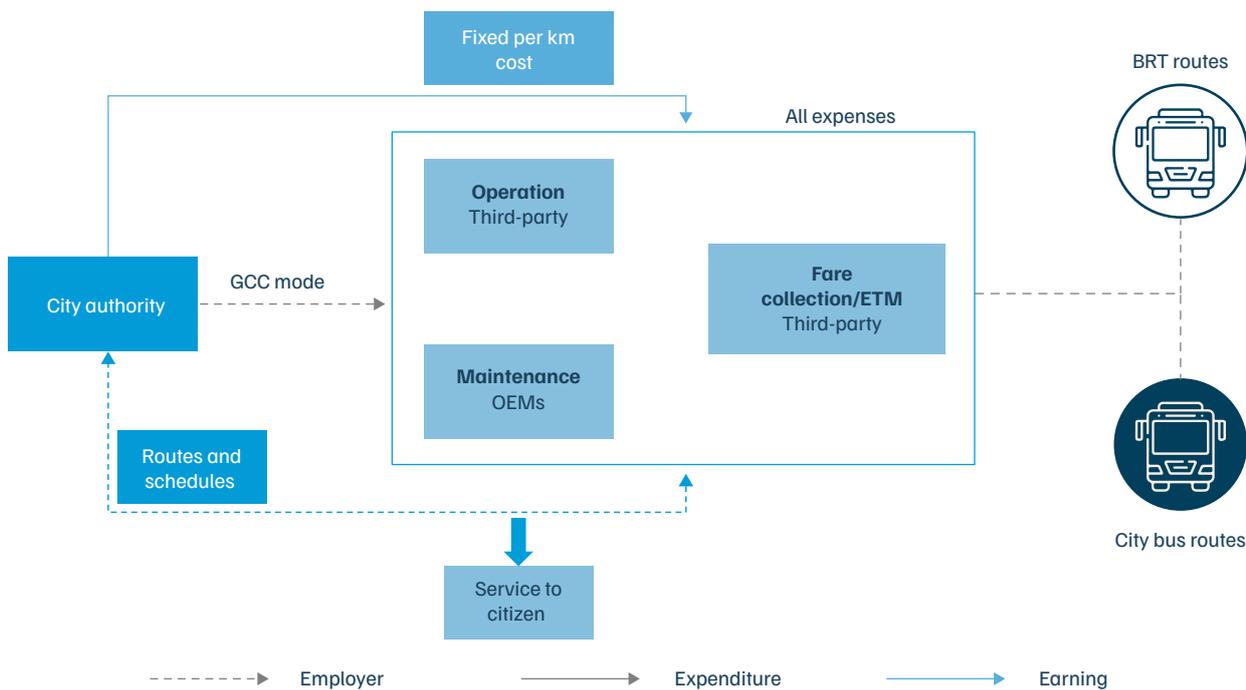
Source: Authors' analysis

Figure 13. Typical net cost contract operations



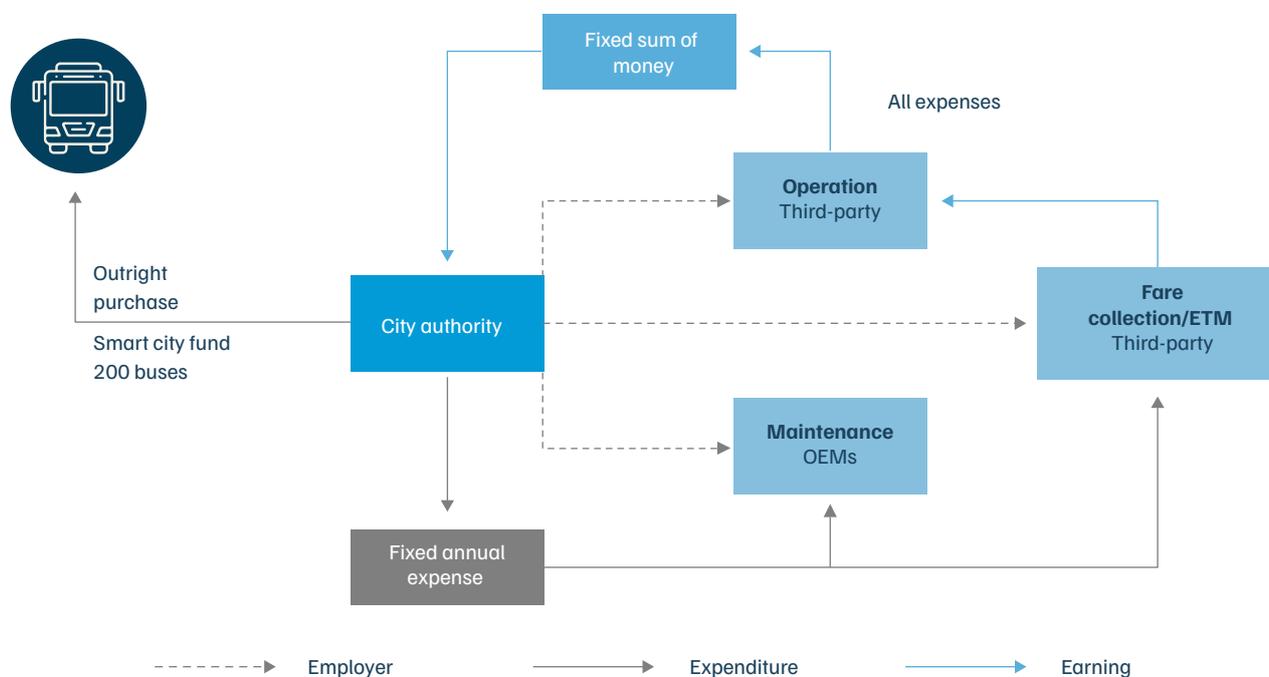
Source: Authors' analysis

Figure 14. Typical gross cost contract operations



Source: Authors' analysis

Figure 15. Guwahati's fixed-revenue model



Source: Authors' analysis

Box 2. How is Guwahati's model different from other prevalent models

As presented in the charts above, Guwahati follows a hybrid operational model that incorporates elements from multiple models. Key features include:

- **Fleet ownership:** The city authority (ASTC) retains ownership of the fleet, similar to the outright purchase model.
- **Operator selection:** Similar to the NCC model, ASTC floated a tender and selected two private operators (each responsible for buses from a specific OEM), where the bidders with the highest premium per km to be paid to ASTC were awarded the contract.
- **Revenue collection:** In Guwahati, unlike the NCC model, ASTC has outsourced revenue collection responsibilities to a third party named CHALO, which pays the revenue to the operators.
- Unlike the NCC and GCC models, in Guwahati, **operators pay ASTC the following charges:**
 - » A fixed standing charge of INR 800 per bus per day
 - » A running charge of INR 8 per km for TATA buses and INR 9 per km for Olectra buses
 - » ASTC decides on the minimum daily utilisation; TATA buses ply a minimum of 80 km per bus per day, and Olectra buses operate at a minimum of 100 km per bus per day

These charges are applicable for a minimum of 26 days per month.

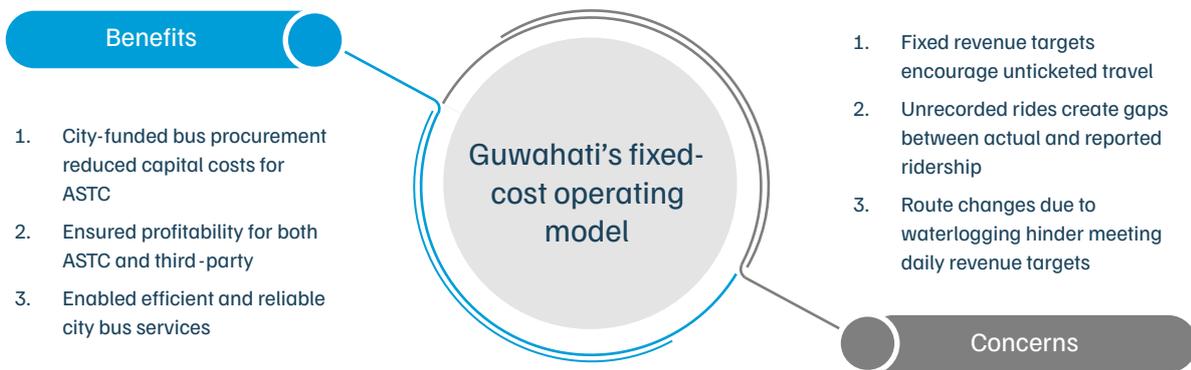
- **Risk allocation:** The private operators bear the risks associated with changes in operational costs and revenues, aligning this aspect with the NCC model. However, the risk of recovering the capital cost remains with ASTC.



Stated challenges

- More than 50 per cent of the FAME I buses (procured in 2019) are retired, and the remaining ones are nearing the end of their battery life. The city authority does not have a plan for managing end-of-life batteries.
- Non-subsidised electricity rates result in high operational costs.
- Due to waterlogging in certain areas, routes are often curtailed and have to be diverted, as water remains a potential threat to batteries in e-buses.

Figure 16. Benefits and concerns regarding Guwahati's fixed cost operating model



Source: Authors' analysis

4.2 Decentralised depot and service planning

Surat, Gujarat, India's first city with the largest 'fully-electrified' bus rapid transit services (BRTS) corridor, covers an area of 462 sq km and has a population of 4.46 million (44.6 lakh), as per the most recent Census (2011). Surat City is a hub of economic activity driven by its textile, diamond, and IT industries. It is one of India's fastest-growing cities, with over 50 per cent of its population coming from other parts of India (Times of India 2019). Thus, the city authority's focus on strengthening the public transport system is vital to meet the growing travel demand and arrest the growth of private vehicles.

Surat Sitalink Ltd. (SSL), a Special Purpose Vehicle (SPV), is formed by the Surat Municipal Corporation (SMC) as a fully-owned subsidiary company, to manage mass public transportation. Currently, SSL operates the city bus services (CBS), BRTS, and the high mobility corridor (HMC) on a gross cost-basis in Surat. By incorporating e-buses into the BRTS, the city aims to be a role model for other cities. Presently, SSL operates a total fleet of 873 buses – 425 diesel and 15 e-buses ply on city bus routes, whereas 433 e-buses operate in the BRTS corridor. SSL aims to phase out the existing fleet of diesel buses by 2026 and increase its e-bus fleet size to 1,300 e-buses by 2030.

Table 13. City statistics of Surat, Gujarat

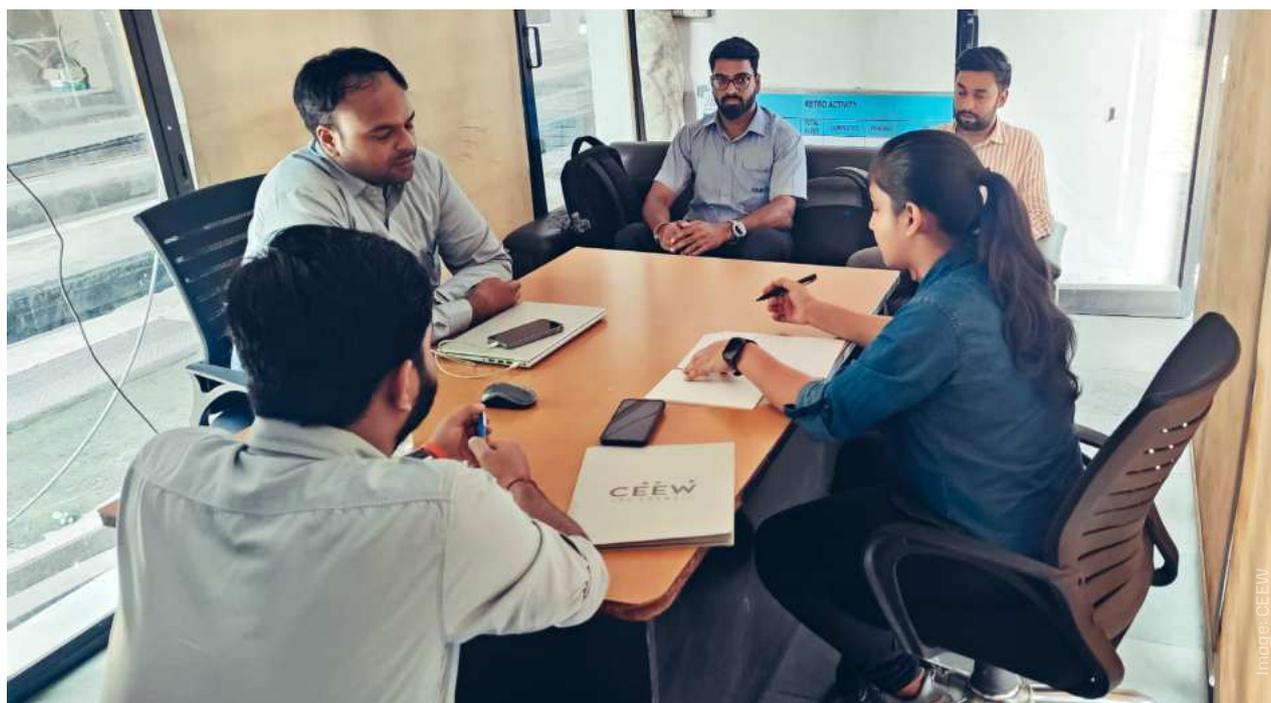
Area	462 sq km
Population (Census 2011)	44,66,826
Popular modes of travel	BRTS buses, city buses, autorickshaws, taxis
Modal share of buses	-

Source: Office of the Registrar General & Census Commissioner, India. Census of India 2011: Provisional Population Totals. New Delhi: Government of India, 2011

Table 14. Bus operation specifications of Surat Sitilink Ltd

Fleet type	Diesel buses	E-buses
Area of operation	Intra-city	Intra-city
Year of operation	2014 (14) and 2024 (425)	2020 (4) and 2024 (450)
Fleet size	425	450
Number of routes	45	13 BRTS routes and 4 city bus routes (common with diesel bus)
Route length in km (min–max)	916 (8–29)	305 (8–34)
Age of fleet (in years)	7 years' contract	2 years on average
Number of depots	4	6
Number of chargers	-	65 fast, 58 slow
Total manpower	1,364	1,710 (419 BRT staff)
Gender ratio (O:F:M)	0:1:22	0:1:58
Number of drivers	464	939
Driver avg. experience	-	8 + years
Mandatory experience	-	5 years
Number of conductors	714	419
Maintenance staff	186	352
Utilisation per bus per day	202	204
Unit Cost of power (INR per kWh)	-	INR 6.9 (subsidised)

Source: Surat Sitilink Ltd.



CEEW team interacting with the depot manager and OEM representative at Bhestan depot, Surat during data collection phase.

Table 15. Bus fleet specifications of Surat Sitilink Ltd

SSL	Diesel bus	E-bus
Operated by	Hansa, Maruti	Chakra, SSP, Greencell, Maha Voyage
Drivers employed by	Hansa, Maruti	Chakra, SSP, Greencell, Maha Voyage
Salary: driver (INR per month)	-	18,500
Salary: conductor	-	-
Maintained by	MJ, Sukani, Akar	Akar

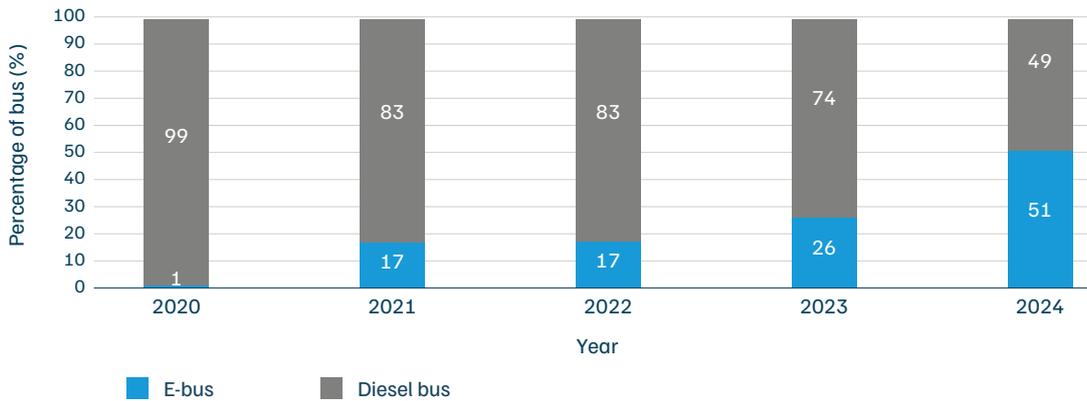
Source: Surat Sitilink Ltd.

Table 16. E-bus fleet specifications of Surat Sitilink Ltd

OEM	Bus type	Fleet size	Scheme	Procurement model
Olectra	9 m	150	FAME II	GCC
Greencell	9 m	150	FAME II	GCC
JBM	12 m	150	NEBP CESL	GCC

Source: Surat Sitilink Ltd.

Figure 17. Surat Sitalink Ltd has been steadily electrifying its bus fleet



Source: Surat Sitalink Ltd.

Surat City's public transport system is organised into nine administrative zones. There are **10 depots strategically distributed across these zones to optimise bus operations and minimise dead kilometres**. 'Dead kilometres' refers to the distance travelled by a public transit vehicle without any boarding/alighting of passengers, typically when moving from a depot to the starting point of a route or from the ending point of a route to the depot. SMC provides land and develops civil infrastructure, while the respective OEMs handle the development of charging and safety facilities. **This collaborative approach ensures that efficient operations and safety standards, along with other necessary features, are developed by the respective OEMs across all depots.**

Table 17. Surat charging infrastructure specifications

Depot name	Bus accommodated	Bus OEM	Bus operator	Number of buses	Number of chargers	Type of chargers	Charger capacity (Kwh)
Bhestan Garden	ICE	Ashok Leyland	Maruti	75	-	-	-
Kosad	ICE	TATA	Hansa	220	-	-	-
VIP Road	ICE	TATA	Hansa	100	-	-	-
Punagam	ICE	TATA	Hansa	30	-	-	-
Palanpur	e-bus	Olectra	Maha Voyage	75	32 AC, 5 DC	Fast/slow	80/150/180
Althan	e-bus	JBM	SSP	25	5	Fast	240
Magob	e-bus	PMI	Greencell	90	12	Fast	180
Vesu	e-bus	PMI	Greencell	65	12	Fast	180
Bhestan BRTS	e-bus	JBM	SSP	75	15	Fast	240
Pal	e-bus	JBM	Chakra	50	10	Fast	240

Source: Surat Sitalink Ltd.

To promote sustainable transit and reduce emissions, **six of these depots are dedicated to e-buses while the remaining four cater to diesel buses**. Each e-bus depot has charging infrastructure installed by the OEMs to support e-bus operations. These depots consume about 0.1 million (1.3 lakh) units of electricity monthly, supplied by Dakshin Gujarat Vij Company Limited (DGVCL) at a rate of INR 6.85 per unit. Efforts to integrate renewable energy are underway, including plans to integrate a pilot 100 kW solar installation at the Althan Depot. This initiative aims to enhance sustainability and reduce dependency on conventional energy sources. Additionally, all OEMs are required to maintain a reserve fleet that can be utilised in case of delays in breakdown resolution.

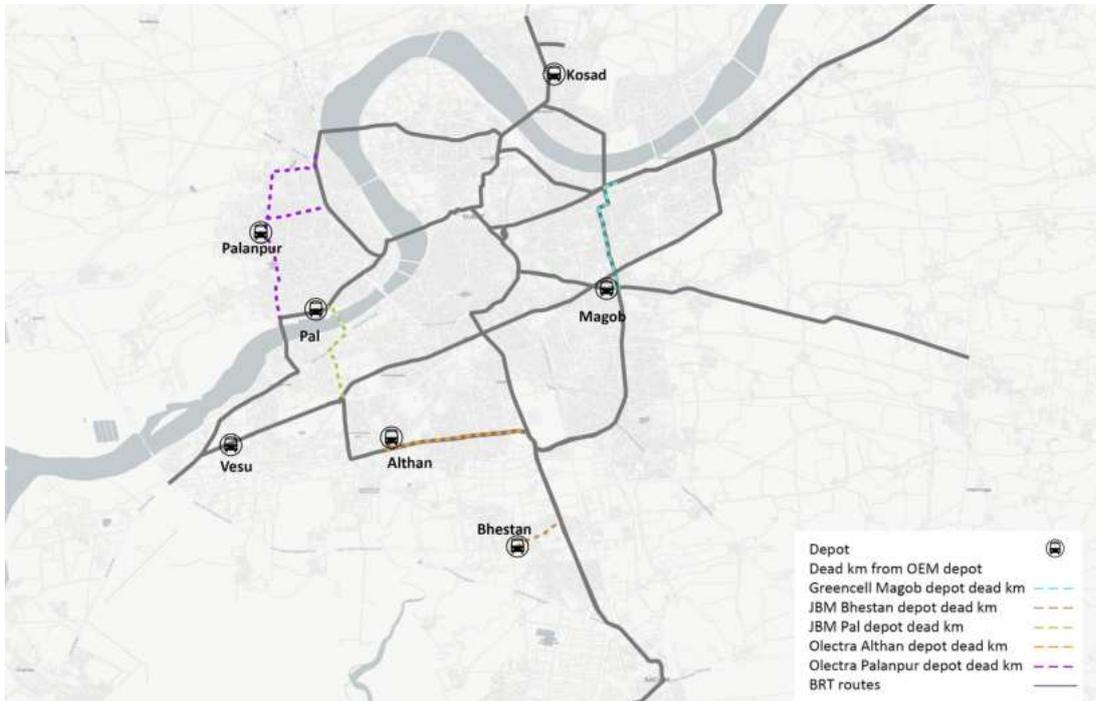
Our scenario analysis shows that decentralised depot allocation keeps the average dead kilometres per trip at 2.2 km, ranging between 0.9 and 2.8 km. This is nearly half the dead kilometres that would result from a centralised depot system—assessed using the Pal depot, which is well located within the city and has the scope of expansion. Thus, **decentralised planning has reduced dead kilometres by 50 per cent, leading to improved route efficiency and lower operational costs** (Table 18).

Table 18. Decentralised depot planning helps reduce dead kilometres per route

Depot planning case	Depot	Route ID	OEM	Average dead km per route (min–max)
Existing decentralised depot planning (BAU) (Figure 18)	Pal, Bhestan, Althan	14, 20, 11, 12, 15AC, 15C	JBM	2.2 km (0.9–2.8 km)
	Palanpur, Althan	13, 17A, 23, 21	Olectra	
	Magob, Vesu	13, 16, 18, 19, 22, 136, 706, 106, 15C	Greencell PMI	
S1 – Centralised depot planning case (Scenario 1) (Figure 19)	Pal	all routes	all OEMs	4.7 km (2.2–10 km)

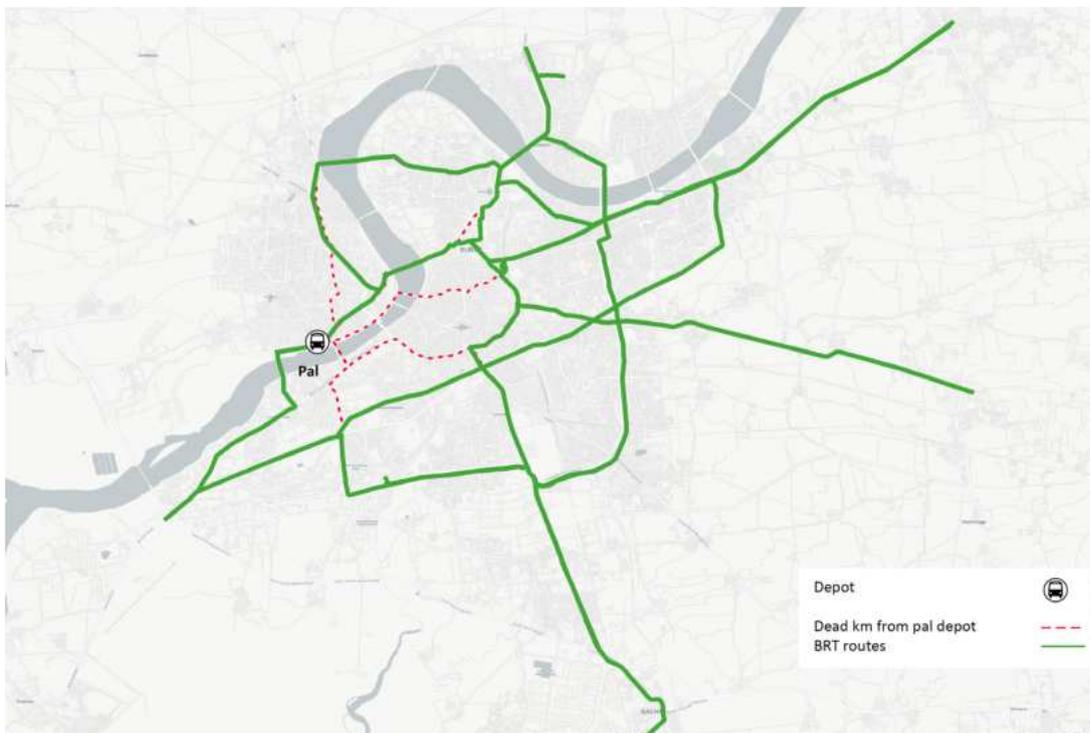
Source: Authors' analysis

Figure 18. In the existing scenario with decentralised depots in Surat, the average dead kilometre is ~2.2 km



Source: Authors' analysis

Figure 19. With a centralised depot, the average dead kilometre in Surat doubles



Source: Authors' analysis

Stated challenges

- SSL aims to procure 1,300 e-buses by 2030, which will require additional land for constructing/expanding depots. The city aims to maintain minimal dead kilometres, so it must acquire land within the city boundaries. As Surat is a highly urbanised city, land acquisition will be a challenge for SMC.
- The electricity cost per unit is a major component of operational costs. An additional 1,300 e-buses will triple the electricity demand, eventually increasing SSL's financial burden. Therefore, a subsidised electricity rate must be provided for robust and efficient operation.

Figure 20. Benefits and concerns regarding decentralised depot planning



Source: Authors' analysis

4.3 Opportunity charging for degraded batteries

Chartered Speed, one of India's largest bus operators, provides services across various states in India, including Gujarat, Maharashtra, Madhya Pradesh, Odisha, Rajasthan, and Assam. It operates across the B2B,¹⁴ B2C,¹⁵ and B2G¹⁶ segments. Chartered Speed offers a range of transport solutions, such as city buses, BRTS, school buses, staff buses, airport buses, taxis, and bike-sharing services. Established in 2010 with an initial fleet of 50 buses, the company has grown significantly and now manages a fleet of 2,200 buses.

Chartered Speed introduced its first set of e-buses in 2019 through a partnership with Atal Indore City Transport Service Limited (AiCTSL), with the aim of electrifying intra-city bus services in Indore. AiCTSL floated a tender under the NCC model, requesting operators to specify the viability gap funding (VGF) needed for operating e-buses.

Chartered Speed adopted a hybrid approach and quoted the lowest VGF, valued at INR 0.3 million (INR 3 lakh) per month for operating 40 e-buses, securing the tender. The company's motivation to transition to electric buses stemmed from achieving cost parity with diesel buses, facilitated by leveraging state and central subsidies. Through the FAME I scheme and Madhya Pradesh state subsidy, Chartered Speed secured a combined subsidy of INR 6 million (INR 60 lakh), reducing the purchase cost of each e-bus to INR 3 million (INR 30 lakh) – which was on par with the cost of a diesel bus. Additionally, under the hybrid NCC model, AiCTSL facilitated land acquisition for the depot and the installation of a charging station.

14. B2B: It is the type of model where services are exchanged between two businesses (companies).

15. B2C: It is the type of model where services/goods are directly exchanged with the end users/customers.

16. B2G: It is the type of model where services/goods are exchanged between a specialised business and the government entity.

AICTSL also pays for e-bus charging costs. Under the contract, AICTSL decides bus fares and routes, while Chartered Speed handles scheduling and fare collection. Chartered Speed has to operate a distance of at least 150 km per bus daily, which is monitored daily by AICTSL. E-buses operate on four routes within the city, covering a total route length of 63.25 km. As mentioned by Chartered Speed, in 2024, 33 e-buses were operational in Indore, catering to around 0.15–0.2 million (1.5–2 lakh) people monthly. **Initially, the buses with 120 kWh batteries offered 90–95 km on a single charge, but now this has been reduced to 65–70 km.**

Table 19. City specifications of Indore, Madhya Pradesh

Area	530 sq km
Population (Census 2011)	19,94,397
Popular modes of travel	BRTS buses, city buses, autorickshaws, bicycles
Modal share of buses (CMP Indore, 2012)	19%

Source: Office of the Registrar General & Census Commissioner, India. Census of India 2011: Provisional Population Totals. New Delhi: Government of India, 2011., Comprehensive Mobility Plan Indore, 2012



E-buses in Indore were first deployed in 2019, and their batteries are now nearing the end of their life.

Table 20. Bus fleet and operation specifications of Chartered Speed Pvt. Ltd. in Indore

Fleet type	E-bus (Chartered Speed)
Area of operation	Intra-city
Year of operation and fleet size	Began in 2019 with 40 buses; 33 operational as of 2024
Number of routes	4
Route length (min–max) km	64 (14–18)
Age of fleet (in years)	5
Number of depots	1
Number of chargers	12 fast
Total manpower	110
Gender ratio (O:F:M)	0:0:110
Number of drivers	48
Avg. driver experience	-
Mandatory experience	5 years
Number of conductors	50
Maintenance staff	12
Utilisation per bus per day	152
Avg. monthly fuel/power consumption	~ 0.3 million (3 lakh)
Cost of energy per km	-
Unit cost of power	INR 6.9 (surcharge of 20% on normal rate)

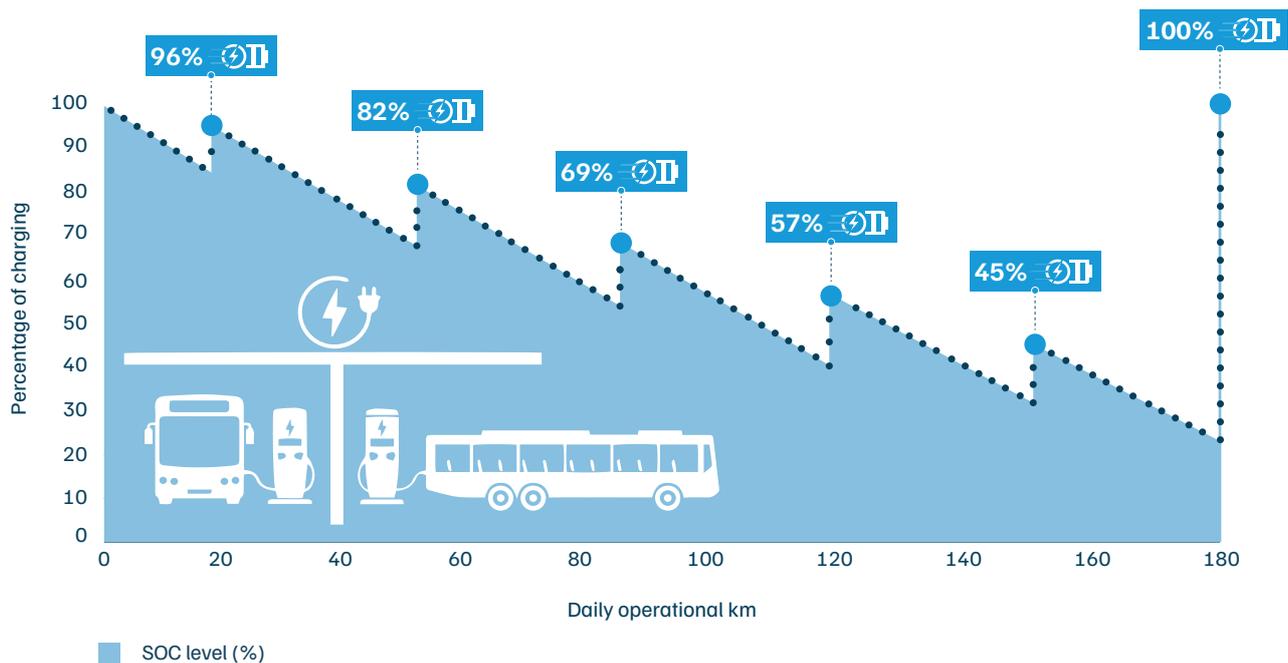
Source: Chartered Speed Pvt. Ltd.

How has Chartered Speed ensured that each bus covers 150 km per day despite battery's depleting age?

Chartered Speed's e-buses in Indore are now five years old. Their batteries are approaching end-of-life. Due to this, buses often experience sudden drops in state of charge¹⁷ (SOC) during operations, which poses challenges for effective operation. Chartered Speed adopted an innovative approach to improve bus utilisation in such situations. **They designed the bus schedules such that each bus could return to the depot every hour or after riding 16–20 km for 15–20 minutes of opportunity charging, which boosted the SOC by 15 per cent.** This arrangement helped prevent breakdowns during the trip. In addition to the 14 chargers installed at the depot, **Chartered Speed installed three opportunity chargers in the city at the start and end of a few routes** to support the opportunity-charging process.

Although this system increases dead kilometres, as buses have to return to the chargers frequently, it ensures that the minimum required operational kilometres are met. As Chartered Speed is responsible for bus timing and scheduling, this process is managed efficiently to balance service quality with operational needs. Figure 21 shows the SOC pattern due to hourly charging throughout the day.

Figure 21. Opportunity charging after every one hour or 20–30 km of operation boosts the battery's state of charge by 15%



Source: Chartered Speed Pvt. Ltd.

17. State of charge (SOC) is a measure of how much energy is remaining in a battery, expressed as a percentage of its full capacity.

Concerns regarding battery degradation

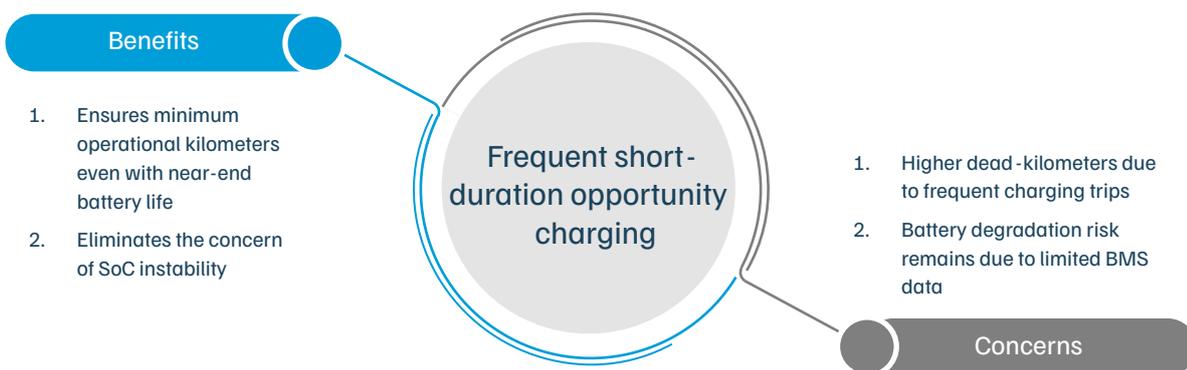
Battery degradation is a significant concern for e-bus operations; frequent charging cycles and shorter cooling periods due to strict scheduling can hasten degradation. Insights from previous case studies highlight that more than half of the buses procured under FAME I in cities such as Guwahati and Lucknow have been retired, primarily due to degraded batteries. In contrast, over 85 per cent of the e-bus fleet procured by Chartered Speed in Indore is still operational. Chartered Speed has reportedly mentioned that there has been minimal battery degradation in its e-buses despite multiple opportunity-charging cycles.

A key challenge in assessing battery degradation is linked to the **inaccessibility of accurate battery management system (BMS) data**, which is locked and controlled by the OEMs. Hence, forcing operators to rely on estimations that may not align with OEM-calculated metrics. For instance, in Indore, Chartered Speed reported that short-duration opportunity charging, such as charging from 20–40 per cent SOC and again from 40–60 per cent SOC are considered as two separate charging cycles by them, but the OEM's BMS consolidates both events as a half charge cycle. This discrepancy makes it difficult to draw accurate conclusions about battery degradation patterns.

Stated challenges

- Chartered Speed, like many early adopters of e-buses, faces significant challenges with end of battery life management. Most batteries experience a reduction in the operational SOC. Initially, batteries operated at an 85 per cent depth of discharge,¹⁸ which has now reduced to as low as **60–65 per cent in some cases**. As e-buses approach the end of their battery life after five years, Chartered Speed faces **challenges in recovering its capital expenditure and operational costs in this short span. In the case of Indore, the losses incurred by intra-city buses were balanced out by the profits generated by inter-city buses, which operated between Indore and nearby cities. The financial pressure to break even is one of the barriers to transitioning the company's ICE fleet to electric.**

Figure 22. Benefits and concerns regarding frequent short-duration opportunity charging



Source: Authors' analysis

18. Depth of discharge (DoD) indicates the percentage of the battery that has been discharged relative to the overall capacity of the battery. It tells how much energy can be safely drawn from the battery before it needs to be recharged.

4.4 E-buses for staff transport services

Chartered Speed began operating dedicated e-buses for staff in mid-2022. The operation commenced with a fleet of four e-buses operating between Ahmedabad and Gujarat International Finance Tec-City (GIFT City), and it has now expanded to 10 e-buses operating in multiple shifts, making two to four round trips daily, catering to employees who travel between Ahmedabad and GIFT City for work. The e-buses are owned by Chartered Speed and were procured under a CAPEX model, with financing obtained at an interest rate of 9.4 per cent. Each bus cost INR 12 million (INR 1.2 crore), and no subsidies were provided for the procurement.

Chartered Speed aims to support the development of a green mobility zone (GMZ) in GIFT City, particularly in the special economic zone (SEZ) area. Additionally, by providing electric staff buses, Chartered Speed helps organisations reduce the emissions associated with employee commutes, as outlined in their Scope 3 declarations.

In 2022, GIFT City had approximately 12,000 employees. The absence of public transit services within the city posed significant challenges for commuting. Employees primarily commuted using private cars, with an average occupancy of two people per vehicle. This led to around 5,000 cars entering the city daily, occupying nearly one million sq ft (10 lakh sq ft) of space, which is worth INR 2 billion (INR 200 crore), estimated based on the local market rate of INR 2,000 per square foot.

Additionally, around 70–80 per cent of employees travelled daily in private vehicles between Ahmedabad and GIFT City, resulting in heavy traffic on the Ahmedabad-Gandhinagar Highway. Chartered Speed operates its staff buses on business-to-customer (B2C) and business-to-business (B2B) models. In the B2C model, staff can pre-book their preferred seats online via the Chartered Speed application. They can book a one-way ticket, a day pass that allows unlimited travel on that day, or a monthly pass that allows unlimited travel in the month. The subscription cost (exclusive of GST) for each type of booking is mentioned here:

- One-way ticket: varies from INR 40 to 200, based on the distance travelled
- One-day pass: INR 300
- One-month pass: INR 3,750

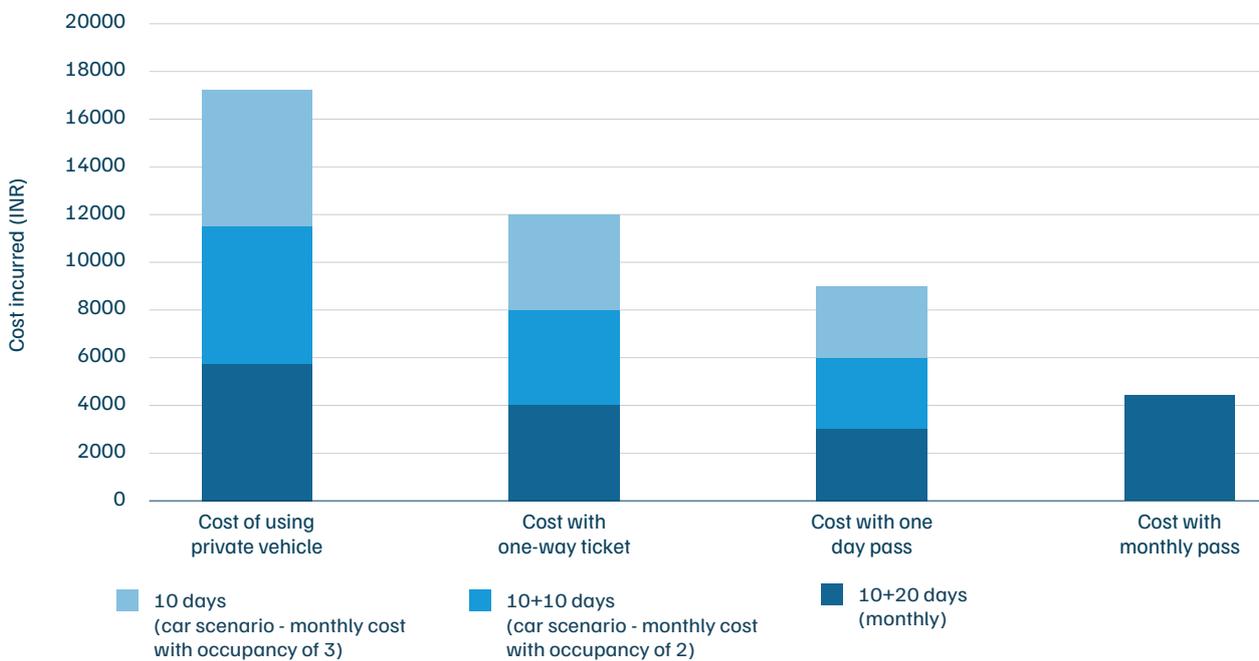
Under the B2B model, Chartered Speed partnered with companies like Adani Airport Holdings and Befree Business Resourcing LLP in Ahmedabad and GIFT City to operate dedicated e-buses for their employees based on the routes and schedules provided by these companies.

The monthly pass system is the most economical option for commuters from Ahmedabad to GIFT City, offered at a monthly subscription of INR 4,425 per passenger. For an employee using a private vehicle with an effective mileage of 12 km per litre, a 70-km round trip will consume 6 litres of fuel, which will incur a daily cost of INR 576 (@INR 96 per litre), amounting to a monthly expense of INR 17,000 or more. **The staff bus arrangement will reduce travel expenditure by almost 75 per cent** (if opted for individually) (Figure 23) and **also benefit partner companies, as it will help reduce the cost of travel allowances and help organisations fulfil sustainability targets.**



Employees boarding a chartered staff shuttle to reach their workplace.

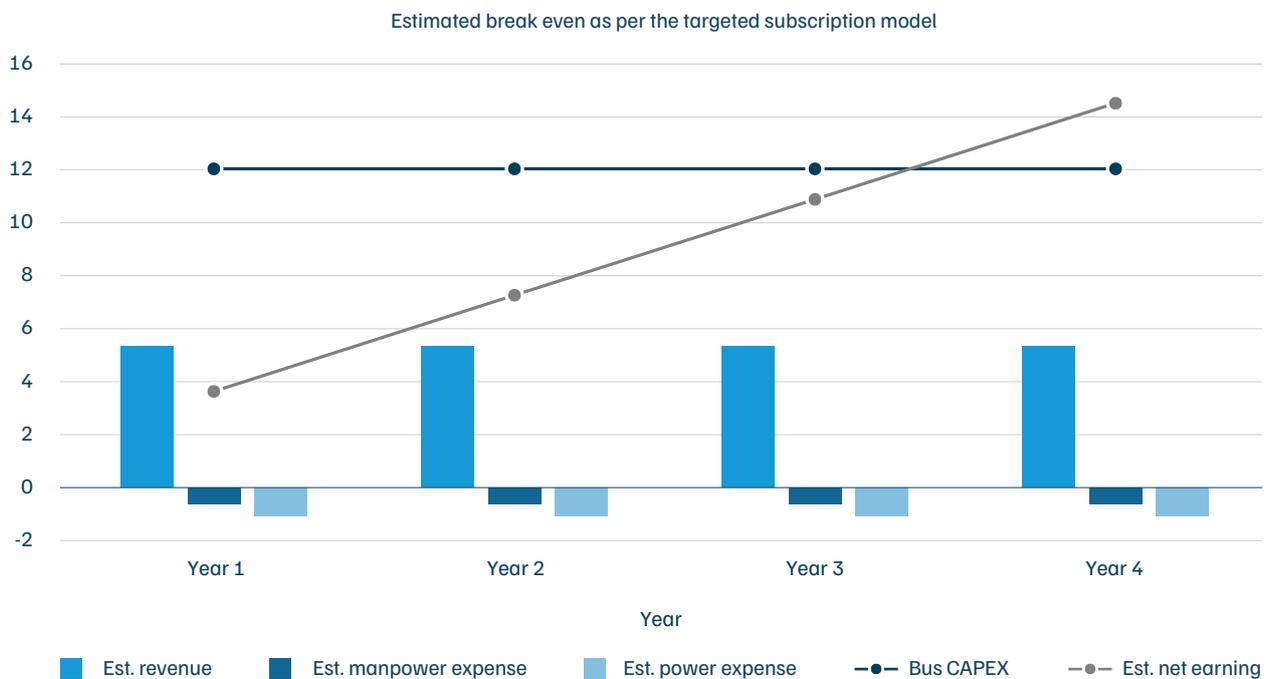
Figure 23. Cost of commuting with a monthly pass is nearly one-fourth that of using a private vehicle



Source: Authors' analysis

The staff bus subscription model by Chartered Speed offers services at INR 2 per km – in this pricing model, staff buses may break even in 3–4 years if they have 100 passengers across three up and down trips. For instance, assuming the cost of a new e-bus is INR 1.2 crore, with a seating capacity of 30 commuters and one driver. Chartered Speed aims to accommodate at least 100 passengers per bus per month on a monthly subscription basis, which will provide a fixed revenue of INR 53 lakh annually. The major components of operational expenditure are power and manpower costs. An e-bus must serve to commute three batches of staff (100 passengers) from Ahmedabad to GIFT city and back to Ahmedabad each day, i.e. six trips of 70 km. The average power consumption of an e-bus is 1.2–1.3 kWh/km, resulting in an energy requirement of 500 units per day, costing INR 9.7 lakh annually (@INR 7/unit). As per the staff requirement of 4.71 per e-bus, the annual manpower expense will be 9.3 lakh, assuming a salary of INR 16,500/staff. This will result in an effective income of INR 34 lakh annually, and the break-even point is expected to be achieved in 3-4 years (Figure 24).

Figure 24. Break-even is estimated to be achieved within 3 to 4 years under the targeted subscription model

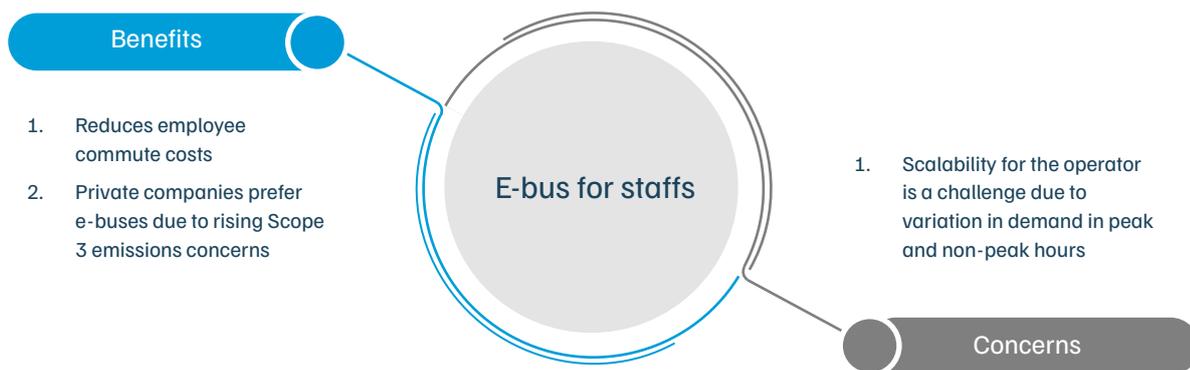


Source: Authors' analysis

Stated challenges

- **Strict break-even target in three years:** to ensure profitability, operators must achieve break-even within three years. This is crucial, as after five years of operation, e-buses will require battery replacements, which will cost nearly 50 per cent of the initial bus capital expenditure. Achieving this goal necessitates a consistent ridership of at least 100 passengers per bus per day to cover costs and maintain financial viability.
- **Operational constraints:** achieving the target of at least 100 passengers per bus per day requires each bus to complete 6 trips, each of around 70 km per day. However, this is challenging, as most companies operate on standard 9-to-5 schedules, leading to concentrated demand during the peak hour i.e. morning and evening. This aggregated demand poses a challenge to meet the required target of trips and passengers.
- **Scalability:** the staff buses can only be used for company use, leading to inefficiency and underutilisation of a green public transit asset during off-peak hours. Therefore, the option of flexible contracts needs to be explored.

Figure 25. Benefits and concerns regarding e-bus for staffs



Source: Authors' analysis

4.5 Retrofitted e-bus initiatives

Kalyani Powertrain Limited (KPTL), a subsidiary of Bharat Forge DNA, has been driving the electrification of two-wheelers, buses, and trucks since 2021, focusing on commercial, environmental, and operational benefits. With a strong emphasis on retrofitting¹⁹ ICE vehicles to transform them into EVs, the company is ambitiously targeting a significant global market share.

Its primary goal is to electrify medium and heavy-duty vehicles (MHDVs) in the 7–18 ton GVW segment, which comprises 7 m (25-seater) to 12 m (45-seater) buses, particularly those aged 5 to 15 years. The company caters mainly to B2B clients but also provides limited B2C services, converting small fleets of 4–6 buses. They have successfully retrofitted school buses, staff buses and inter-city buses, details of which can be found in Table 21.

19. "Retrofit" means replacing the combustion engine drivetrain from a vehicle and fitting EV kit

Table 21. E-buses retrofitted by Kalyani Powertrain

S. no.	Vehicle type	Length/seater	AC/non-AC	Range per charge	ARAI certificate	City of operation (trials with customers)
1	School bus	7 m/25	Non-AC	100+ km	In progress	Pune
2	Staff bus	9 m/35	AC	150+ km	Yes	Mumbai
3	STU/inter-city	12 m/45	AC	220+ km	Yes	Kanpur, Pune - Mumbai

Source: Authors' analysis

The company aims to significantly reduce overall electrification costs. Kalyani Powertrain has partnered with financial institutions to address the high upfront costs of vehicle electrification, particularly for trucks, providing a 'one-stop solution', from fleet electrification to financing alternatives at reduced interest. This partnership ensures cost recovery within three years, alleviating the concerns of hesitant investors and encouraging the adoption of electric solutions.

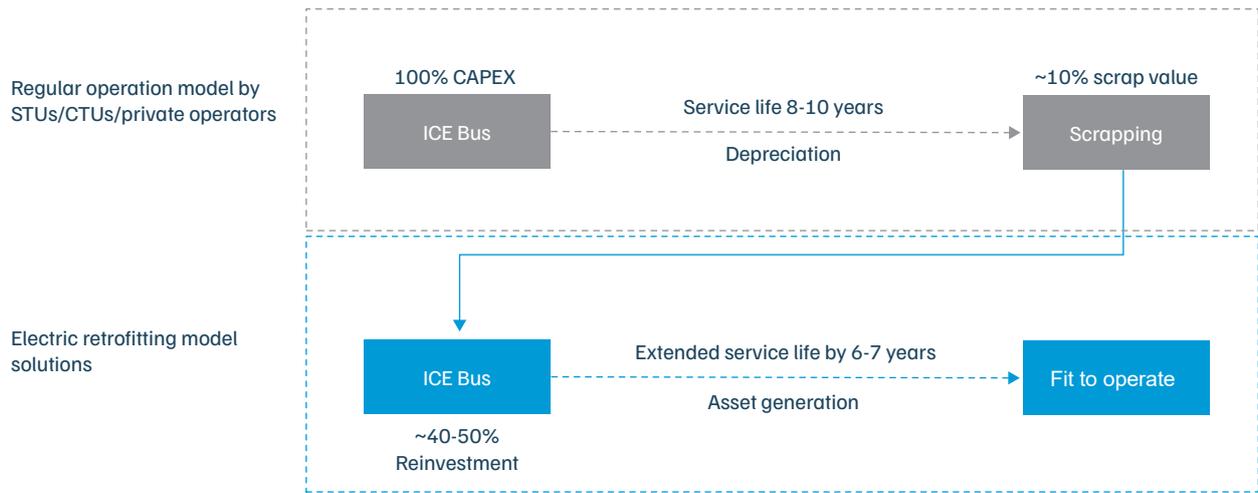
Business model and operation

Kalyani Powertrain offers electric retrofitting for buses that are about to retire after about 5 to 15 years of service. After the necessary approvals have been obtained, all ICE components, including the engine, are removed, a new EV kit is installed, and the internal structure and layout are redesigned. The refurbished bus model undergoes testing by the Automotive Research Association of India (ARAI). The approval process includes tests for vehicle weight changes, gradeability, brake performance, noise levels, motor power, the safety compliance of traction batteries, and functional safety. Further, wiring harnesses and connectors are tested for durability, voltage resistance, and compatibility with various conditions. The whole process generally takes around two months to complete, including the first-time homologation²⁰ process. After the one-time homologation of a particular model manufactured in a particular year is completed, it takes less than a month to convert a diesel bus into an e-bus. Kalyani claims that their retrofitted buses and trucks offer an efficiency of 0.6–0.8 kWh per kilometre on plains and 1.1–1.3 kWh per kilometre across varied terrains and slopes. The initiative focuses on converting inter-state ICE buses to EVs. While these ICE buses ideally have a lifespan of around 15 years, they are typically taken off the road after 8–10 years of operation. This is often due to a degraded chassis or frequent engine breakdowns. **KPTL states that retrofitted e-buses offer the government a cost-effective solution, costing only 40 – 50 per cent of the price of a new e-bus—approximately INR 7 million (INR 70 lakh), compared to around INR 15 million (INR 1.5 crore) for a new e-bus.** Additionally, retrofitting can extend the lifespan of a bus by another 6–7 years, thereby ensuring that **the vehicles are utilised to their full intended lifespan of approximately 15 years** (Figure 26).

Using the CEEW's e-bus viability model, the study found that the TCO of retrofit buses is lowest after 40 km of utilisation per day, and would be 20–23 per cent lower than that of ICE buses for a daily bus utilisation of 180–200 km (Figure 27). Hence, retrofitted e-buses can be a viable solution for intra-city and inter-city buses based on the use-case-wise bus utilisation shown in Table 6.

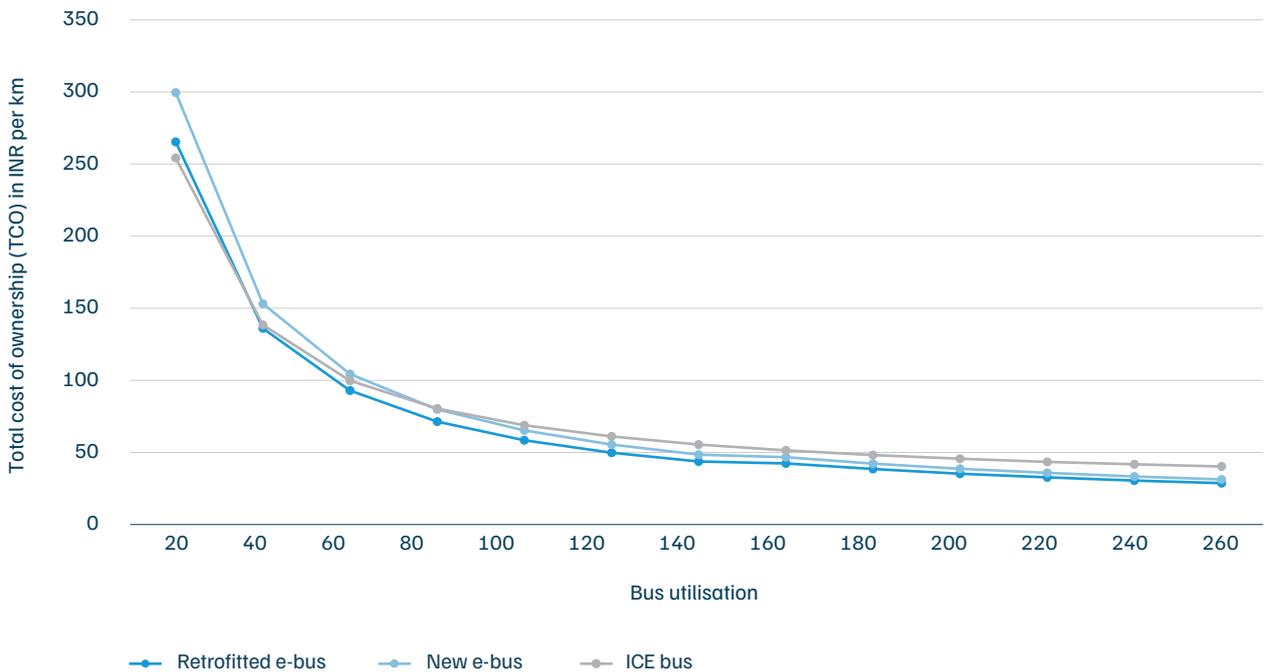
20. Homologation is the process of certifying that a particular vehicle is roadworthy and matches certain specified criteria laid out by the government for all vehicles made or imported into that country.

Figure 26. Retrofitting ensures the utilisation of vehicles until their ideal lifespan of ~15 years



Source: Authors' analysis

Figure 27. Retrofitted e-buses offer a lower total cost of ownership (TCO) for daily utilisation exceeding 40 km in comparison to ICE bus and new e-bus



Source: Authors' analysis

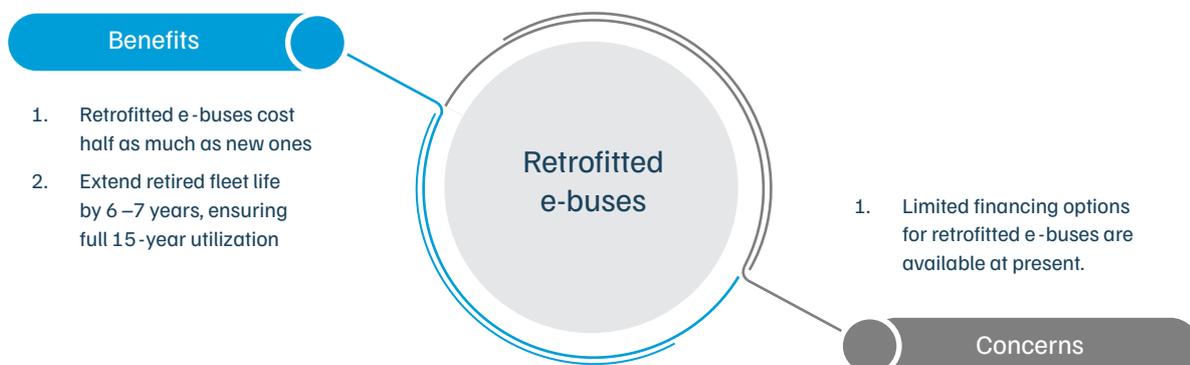


Kalyani Powertrain Ltd. team removing ICE engine parts to retrofit it into an e-bus.

Stated challenges

- Scalability:** Older vehicles' testing and approval processes take a long time, delaying the delivery of refurbished vehicles. As suggested by Kalyani Powertrain, relaxation in AIS-123 (Part 3) norms (CMVR Type Approval of Electric Propulsion Kit Intended for Conversion of Vehicles for Pure Electric Operation) will catalyse electrification at scale and encourage various CTUs/STUs and private operators to opt for cleaner and greener technology at a much lower cost.
- Registrations:** Another challenge is the inconsistent documentation of retrofitted vehicles on the Vahan Dashboard – retrofit vehicles appear under both EV and ICE sections – resulting in inaccurate data. Additionally, after passing RTO tests, these vehicles are registered as EVs and not under a separate category for retrofitted models. They also miss out on benefits like subsidies or tax exemptions, especially with the conclusion of the FAME II scheme.

Figure 28. Benefits and concerns regarding retrofitted e-buses



Source: Authors' analysis

4.6 Battery-swappable e-bus pilots

The high upfront cost of e-buses is a significant challenge to their uptake. The capital cost of an e-bus is two to three times higher than that of conventional buses (Kumar, Mulukutla, and Doshi 2024). Batteries alone account for about 40 per cent of the cost of e-buses (WRI India 2024). Using battery-swapping technology significantly lowers the upfront cost of e-buses, enhancing their cost competitiveness with conventional vehicles.

Battery-swapping technology, which was primarily used for two- and three-wheelers in India, has now been expanded to larger vehicles. In 2019, Ashok Leyland led the first efforts to deploy 18 swap-capable e-buses in Ahmedabad in association with SUN Mobility, a leading battery-swapping operator (ITDP 2022).

The primary motivation for Ahmedabad's one-year-long battery-swapping in buses pilot was to trial the utilisation of lighter batteries, enabling higher passenger loads without compromising performance and minimising downtime, as swapping allows buses to resume operations quickly, similar to ICE buses.

Pilot in Ahmedabad: 2019

In 2018, India's first swap-capable bus, the Circuit-S, was uniquely designed for Indian mass transport with compact and lightweight batteries that could be easily swapped at the end of a route, while also creating more passenger space and standing room. In 2019, the Ahmedabad Municipal Corporation (AMC) tendered 18 of these buses from Ashok Leyland under the gross cost model, where Ashok Leyland owned, operated, and maintained the buses. AMC paid the company INR 12.5 per kilometre (WRI and SHAKTI 2021). However, by early 2022, all the swap-capable buses had been converted to operate with plug-in charging due to several issues

- **Fleet size and operations**

Over 12 months, the swap capable buses covered over 0.65 million (6.5 lakh) kilometres, completing 20,000–25,000 trips with approximately 25,000 battery swaps. The pilot project was deployed on routes with a round-trip length of about 30 km, where each bus completed three to four round trips a day, and at the end of one circular trip, the buses' batteries were swapped (Swamy 2022). A single swapping station was set up at the depot to support the 18 buses. These vehicles had a maximum passenger capacity of 50 and a range of up to 40 km per swap, and operated on 60 kWh batteries.

- **Economic impact**

Ashok Leyland's swappable buses demonstrate a positive economic impact. They operate at a rate of INR 63 per km while delivering notable fuel economy of INR 7.20 per km, significantly lower than their ICE counterparts' INR 18 per km (Wangchuk 2019).

This makes them more cost-effective for daily operations while providing the environmental benefits of e-buses. Additionally, their lower upfront cost enhances their financial viability, making the battery-swapping model an economically attractive solution for sustainable public transport. However, the pilot was stopped during the COVID-19 pandemic in late 2019 and early 2020. The buses were parked in the depot for three to four months, causing battery deep discharge. After COVID, the swapping station was shut down, and Ashok Leyland took back all the buses.



Battery of Veera Vahana's 10.5m bus being swapped at SUN Mobility's station during Prawas 4.0.

Industrial pilot in Bengaluru: 2024

After the battery-swapping pilot in Ahmedabad, an industrial pilot of swap-capable e-buses was launched in Bengaluru, showcasing advancements in battery-swapping solutions for heavy vehicles. The pilot utilises 10.5 m e-buses developed by Veera Vahana, with swapping services provided by SUN Mobility, which owns the batteries and swapping station.

The same bus model accommodates two battery configuration options – 100kWh + 100kWh or 100kWh + 50kWh – which offers operators the flexibility to deploy the buses on inter-city and mofossil routes. During the ongoing pilot, the bus operates in a closed-loop setup within a campus environment without passengers, allowing evaluation of vehicle performance, battery efficiency, and operational range. The observed ranges are approximately 85–90 km for the 100 kWh battery and 40–50 km for the 50 kWh variant. The swapping time is reported to be between 2.5–3.0 minutes, and the cost of the swap-capable e-bus without battery stands at INR 6–7 million (60–70 lakh).

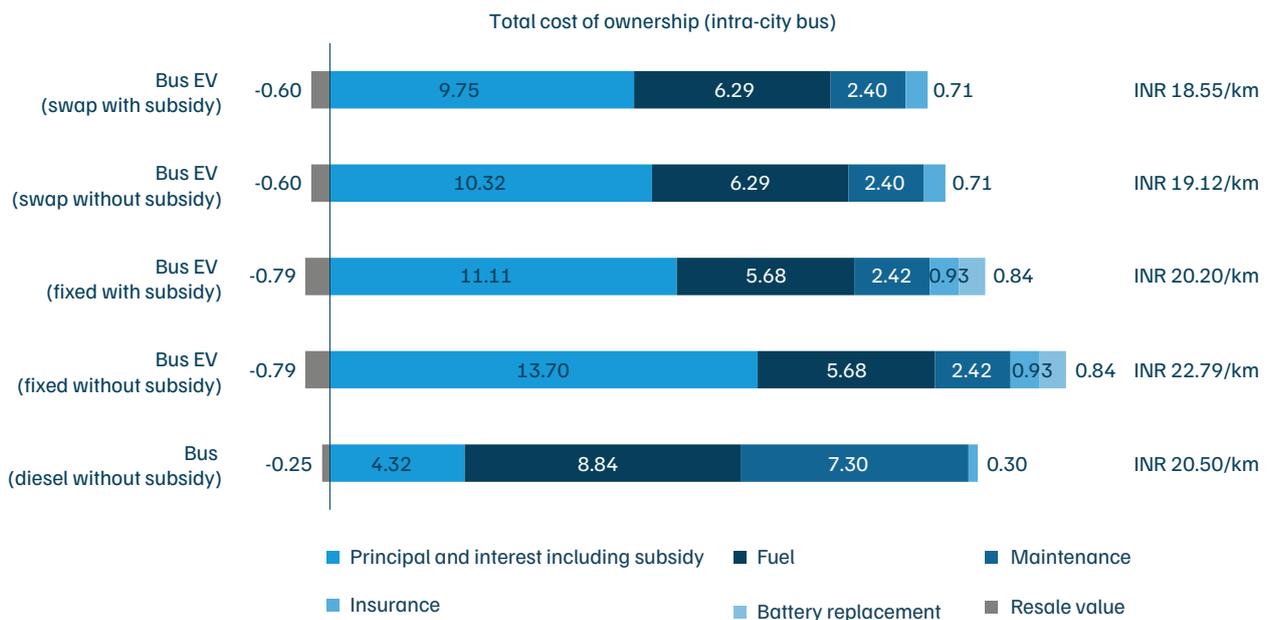
- **Fixed battery vs swappable battery for buses**

- » Swap-capable buses cost up to 40 per cent less than fixed-battery buses.
- » Battery swapping offers shorter recharging times than point charging. Point charging of fixed-battery buses takes several hours to charge using a slow charger and about 40 minutes using a DC fast charger. In contrast, battery swapping takes only about three to six minutes.
- » As per the India Battery Swapping Association (IBSA), battery swapping requires only one acre of land for every 100 buses in contrast to fixed charging, which needs five acres of land for the same number of buses. Additionally, the pilot revealed that battery-swapping stations require significantly less space than traditional vehicle charging stations, making them a more space-efficient solution.

- » Setting up a bus-swapping station is more expensive than establishing a public point-charging station. Each swapping station costs around INR 6–15 million (60 lakh to 1.5 crore), but overall, the TCO for swap-capable buses is cheaper than that for fixed-battery buses.

Our TCO calculation (Figure 29) also suggests that bus battery swapping is more attractive than fixed charging and diesel alternatives.

Figure 29. The total cost of ownership for intra-city swap-capable buses is lower than that of fixed-point charging buses

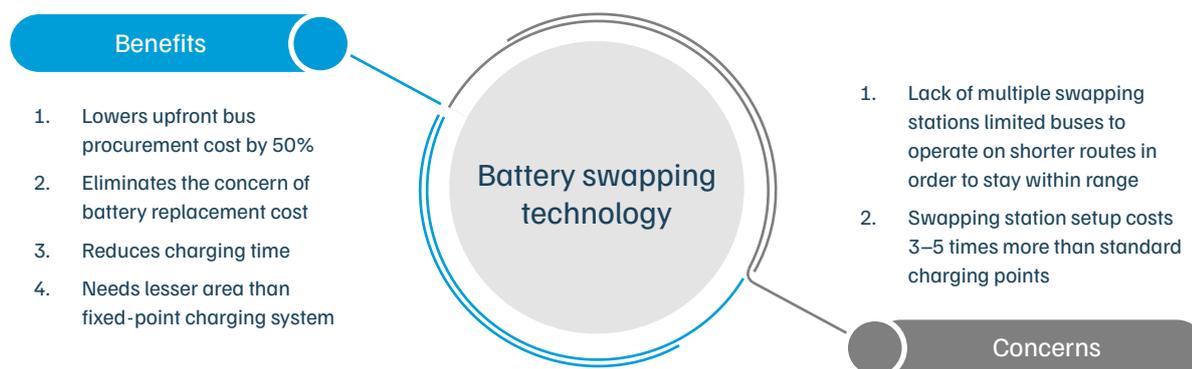


Source: Authors' analysis

Challenges in Ahmedabad's battery-swapping pilot

- **Range limitation:** Implementing battery-swapping technology for e-buses in Ahmedabad was challenging because the batteries used were small, lightweight, and had a low capacity (60 kWh), providing a range of only 40 km per swap. **This limited range led to range anxiety among drivers.** Although this design allowed for quick swaps, taking only 3–5 minutes per swap, the **high number of swaps required reduced overall operational efficiency, making it challenging to provide the seamless service required for long-distance travel.**
- **Required critical mass:** Until bus operations are sufficiently scaled up, the high cost of installing swapping stations for buses presents challenges. Further, modification of the bus design to reduce the size of the battery is an urgent need for the large-scale adoption of this technology (AEEE 2021).

Figure 30. Benefits and concerns regarding battery swapping in e-buses



Source: Authors' analysis

4.7 Gender inclusion in the e-bus workforce

NueGo, India's first inter-city e-bus service, launched by Greencell Mobility in 2022 is operating in over 100 cities across the country. It aims to provide clean, quiet transportation for all. It aims to integrate and create powerful connected platforms/ecosystems across the products and services in the value chain, offering a robust e-mobility infrastructure in the B2G, B2C, and B2B domains.

As of 2024, NueGo operates over 300 buses with around 450 daily departures on more than 100 routes. It employs more than 1,500 staff, including coach captains (drivers) and cabin hosts. Out of this, around 10 per cent of the staff are women and members of the LGBTQIA+ community. The female coach captains, along with male or female cabin hosts, operate mainly on the Delhi–Agra and Delhi–Chandigarh routes as an initiative to empower women and ensure their safety.

Table 22. Operations of NueGo inter-city e-buses

Fleet type	E-bus
Area of operation	Inter-city
Year of operation	2022
Year of employing women drivers	2023
Fleet size	250+
Number of routes	100+
Route length (min–max) (km)	150–500
Age of fleet (in years)	2
Average daily utilisation (in km)	650
Workforce size	1500+
Experience requirement	Min 5 years

Source: Authors' compilation from Focus Group Discussion



Women drivers of NueGo's intercity e- bus.

Women as bus drivers

Bus driving has traditionally been a male-dominated sector. However, the ease of driving an e-bus has opened up opportunities for women to participate in the driving workforce. To promote equal pay and inclusive employment, Greencell Mobility has on-boarded women across various roles, including coach captains, cabin hosts, depot heads, senior managers, and board members.

The female coach captains are highly skilled and experienced in driving heavy vehicles. They have three to five years of heavy vehicle driving experience. While there is no minimum education criteria, most have at least passed the intermediate grade or hold a graduate degree. At the time of joining, before being deployed to the field, they undergo a mandatory 5–7 days training programme conducted by Greencell. This includes three days of theory classes and simulator training to build driving confidence, followed by practical driving experience at the depot and supervised trial runs on the route with an experienced driver and trainer. This one-time training concludes with a theory exam, which must be passed to qualify for the job. The training modules and patterns remain the same for both male and female pilots. Some of the measures implemented by NueGo to encourage and retain female pilots are as follows:

- **Flexible work times:** Steering hours typically begin after 7 a.m., allowing staff to manage household responsibilities in the morning.
- **Same-day return:** Female drivers are as well-trained as their male counterparts to operate on longer routes. However, for their convenience, they are primarily assigned shorter routes such as Delhi–Agra and Delhi–Jaipur, allowing them to return home the same day and avoid overnight stays in another city.
- **Work-hour limits:** Driving hours are capped at a maximum of 10 hours per day, with one mandatory weekly day off being mandatory.

- **Specialised training:** Female drivers receive specialised training in personality development and effective communication with passengers and on-road individuals. This helps them manage passenger interactions calmly and take appropriate action in cases of misconduct.
- **Fatigue management and work–life balance:** The training program includes a dedicated module on managing work-related fatigue and maintaining a healthy work–life balance.
- **Meditation and counselling:** Greencell emphasises reducing the mental stress of both male and female drivers. To achieve this, it has collaborated with local non-profit organisations, including the Brahma Kumaris and Isha Foundation, which provide meditation services and counselling support to drivers whenever needed.
- **Special initiatives such as 'Breaking Barriers with NueGo':** To inspire and celebrate its female coach captains, NueGo launched the 'Breaking Barriers with NueGo' campaign on National Girl Child Day 2024. As part of this initiative, the company honoured its women drivers and cabin hosts by sharing video interviews and profiles highlighting their motivations, challenges, and achievements in the mobility sector.
- **Women's safety:** Depots are provided with dedicated security, relaxing rooms, CCTVs, alcohol checks, background verification, and so on to ensure the safety of staff.

How is the training at NueGo different from the training offered by other OEMs?

Table 23. Comparison of drivers' training offered by various OEMs

	TATA Olectra JBM			NueGo
Training duration (in days)	3	3–5	3	7
Training modules/ pattern	-	-	Day 1: A. Vehicle familiarisation B. Confidence build-up C. Behaviour training Day 2: A.Safe driving practices Day 3: A.Vehicle exploration B.Personal interaction C.Safety rules D.Special-case training like dealing with fire on-board E.30-question written exam	11 modules divided across 3 -5 days. 1. Know your vehicle 2. Hazard inception 3. Traffic control measure mechanisms 4. Lane management 5. Handling intersections 6. Driving in difficult conditions 7. Speed management 8. Personal factors affecting safe driving 9. Fatigue management 10. Personality development 11. Route risk assessment & defensive driving training
Simulator training facility	NA	NA	NA	Yes
Minimum experience required for hiring drivers (in years)	3	3	5	5

Motivation for women to become coach captains

In our in-depth interviews (IDIs) with four female coach captains, they mentioned that learning how to drive an e-bus was comparatively easier than learning to drive a CNG or diesel bus. E-buses are also simpler to operate than ICE buses, as changing gears is not a burden here. Driving commands and instructions appear on the dashboard, such as which gear to apply, overspeeding warnings, lane change assistance, forward collision avoidance, and adaptive cruise control. The training on the simulator helped boost driving confidence; thus, it was easier to operate the buses on the road.

Unlike in ICE buses, handling vehicle breakdowns in e-buses is easy. In most cases, restarting the vehicle automatically fixes the issue, reducing stress for the captain. They can even change the tyres of the vehicle alone or with the help of the conductor. This is because of the lighter weight of an e-bus compared to other fuel-powered buses. In the event of a major fault, the back-end team immediately sends a backup vehicle, ensuring minimal disruption of the bus schedule.

Driving convenience

- Reduced noise and vibration inside the cabin help reduce fatigue and increases work efficiency.
- An adjustable driving seat allows for a comfortable driving position.
- Personality development training enhances passenger interactions.
- The smart dashboards of e-buses simplify the driving process, reducing mental stress while driving.

Social benefits

- Female drivers frequently receive appreciation from the public for driving e-buses. Society acknowledges their work, providing them with additional motivation.
- Many girls and women have expressed interest and have inquired how to become drivers like them.
- Captains feel proud to drive a vehicle that does not pollute the environment.

Stated challenges

- **Limited female participation in a male-dominated industry:** Despite the ease of driving an e-bus, the public transport sector remains heavily male-dominated, discouraging women from considering a career as a coach captain. The perception that bus driving is physically demanding and unsuitable for women results in a lower female participation rate in this sector. However, the growing presence of female drivers in e-bus sector is gradually challenging this notion, inspiring more women to step forward.
- **Breaking social taboos about women driving buses:** The societal belief that women cannot safely operate heavy vehicles poses a significant challenge. Overcoming these biases requires the creation of continuous awareness campaigns and real-life success stories to demonstrate that women are equally capable of managing long-haul bus operations.

- **Need for awareness to encourage more women:** Seeing other female drivers in action provides motivation, but greater visibility of their achievements, training programmes, and career growth potential is necessary to attract more women to the profession.

4.8 Operation of e-buses at mass gathering events

The Maha Kumbh Mela, which happens every 12 years, has been occurring for centuries. The festival finds its roots in the idea of spiritual and physical cleansing, revered deeply in Hindu traditions. The Kumbh Mela, the largest gathering of mankind, was named a UNESCO Intangible Cultural Heritage in 2017. More than 660 million (66 crore) holy dips were counted at the Prayagraj Maha Kumbh 2025, hosted over a period of 45 days.

Table 24. Prayagraj city statistics in the context of Maha Kumbh 2025

Area of Prayagraj	367 sq km
Area of tent city	40 sq km
Population of Prayagraj	11,12,544
Estimated pilgrims	450 million (45 crore)
Mode of travel within the tent city	Walking, two-wheeler, e-rickshaws

Source: Office of the Registrar General & Census Commissioner, India. Census of India 2011: Provisional Population Totals. New Delhi: Government of India, 2011. , Prayagraj Mela Authority

Table 25. Bus operation specifications of Prayagraj during Maha Kumbh 2025

Fleet type	E-bus
Area of operation	Intra-city
Year of operation	2025
Fleet size	200
Number of routes	17
Route length in km (min–max)	203 (5–45)
Age of fleet (in years)	Avg. 3 years
Number of depots	4
Number of chargers	40
Number of drivers	500
Number of conductors	500
Avg. utilisation per bus per day (km/bus/day)	149 km per day and maximum 267 km per day

Source: Directorate of Urban Transport

Transportation during the Maha Kumbh

The Government of Uttar Pradesh anticipated that a huge number of pilgrims will be attending the Maha Kumbh, requiring well-coordinated and integrated infrastructural planning. To achieve this, over 2,600 CCTV cameras were installed for real-time crowd management, supported by AI-driven crowd density mapping to ensure efficient control and safety. An integrated command and control centre (ICCC) was set up at the Maha Kumbh to enable one-stop, real-time monitoring and coordination. In total, 550 intra-city buses, including 200 e-buses, were deployed to ferry pilgrims across the city. The Indian Railways ran 13,450 trains, including special and additional services, to accommodate the massive influx of pilgrims. For inter-city travel, 7,000 UPSRTC buses were deployed to transport pilgrims from various districts across the state and from other states. To enhance connectivity across riverbanks, 30 pontoon bridges facilitated pedestrian movement, reducing pressure on existing road infrastructure.

E-buses in the Maha Kumbh

In a bid to promote sustainable transport, the state government ran 200 e-buses operated by a Greencell/PMI consortium as part of the city's shuttle bus fleet. These e-buses, with a range of more than 150 km, ran on 17 planned routes that ferried thousands of pilgrims across the city. To achieve this task, the Directorate of Urban Transport, under the aegis of the Department of Urban Development, gathered the fleet from three different cities – 35 buses from the state capital Lucknow, 75 buses from Kanpur, and 40 buses from Agra – adding them to the existing fleet of 50 buses in Prayagraj (Figure 31). These buses offered a safe, affordable, economical, and environmentally sustainable way to move millions of pilgrims while reducing emissions and the reliance on private vehicles. Thus, it demonstrated the potential for e-bus operations in future mass gatherings.

Figure 31. Routes taken by e-buses to reach Prayagraj



Source: Authors' analysis

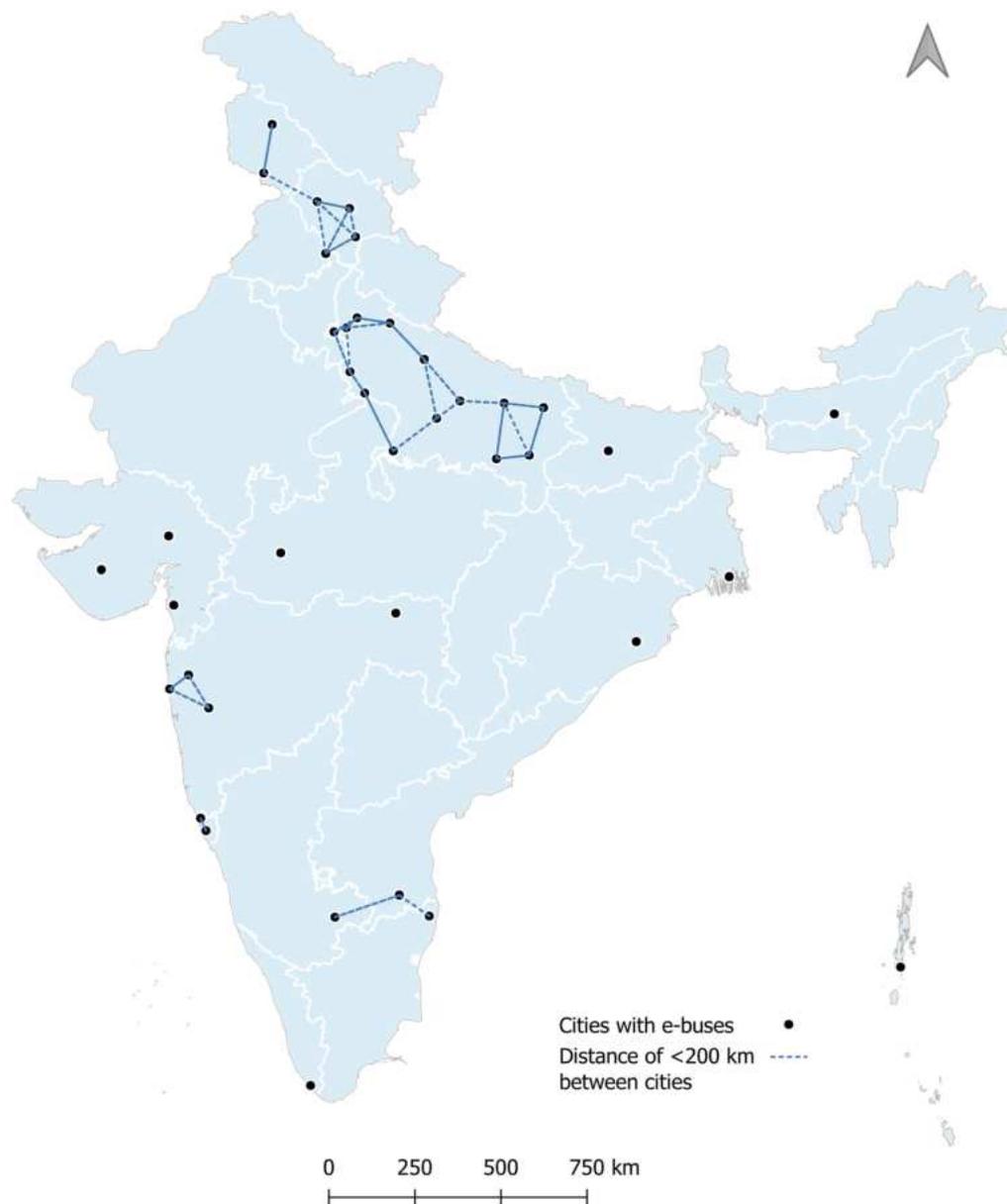


Pilgrims availing e-bus services during the Maha Kumbh Mela.

State-wide coverage of bus charging infrastructure – potential for rapid expansion

The buses from these three cities made extensive journeys to reach the Maha Kumbh grounds. From Kanpur, fully-charged buses made a 200 km-long journey on a single charge, fully testing their abilities. Buses from Agra made a journey of more than 800 km, using the charging depots of the nearest e-bus operating cities on their way to Prayagraj—Agra, Aligarh, Moradabad, Bareilly, Shahjahanpur, Lucknow, and Ayodhya. Similarly, buses from Lucknow arrived at Prayagraj through Ayodhya. An e-bus can travel from Meerut to Varanasi and from Gorakhpur to Jhansi, making a journey of more than 800 km and 600 km across the extreme ends of the state, by using the current charging infrastructure of city bus services. Thus, Uttar Pradesh can boost e-bus coverage for the entire state due to its strategically-placed depot locations/SPV city e-bus services. Further, this phenomenal journey also shows the state's investment in public transportation and charging infrastructure coverage, highlighting the capacity of the state to expand its e-bus network rapidly.

Figure 32. Uttar Pradesh offers state-wide coverage of e-bus charging infrastructure



Source: Authors' analysis

Temporary infrastructure development and deployment of workforce

For the operations of these e-buses in Prayagraj, three temporary charging stations were built at Nehru Park (West), Bela Kachar (North), and Andawa (East), along with the existing charging station at Naini (South). The planning of depots and routes were done on major roads (national highways) and parking to ferry people to the Sangam area. These four stations, located along the city's four cardinal directions, provided overnight and opportunity charging, preventing dead kilometres and increasing the efficiency of bus operations. Along with the charging depots, tents and other facilities were also developed for e-bus drivers, conductors, and other staff members near the three temporary depots. The temporary depots eased operations, improved operation time, and reduced dead mileage by 40 per cent (Figure 33).

Figure 33. Decentralised temporary depots minimised dead kilometres by 40% in Prayagraj during Mahakumbh



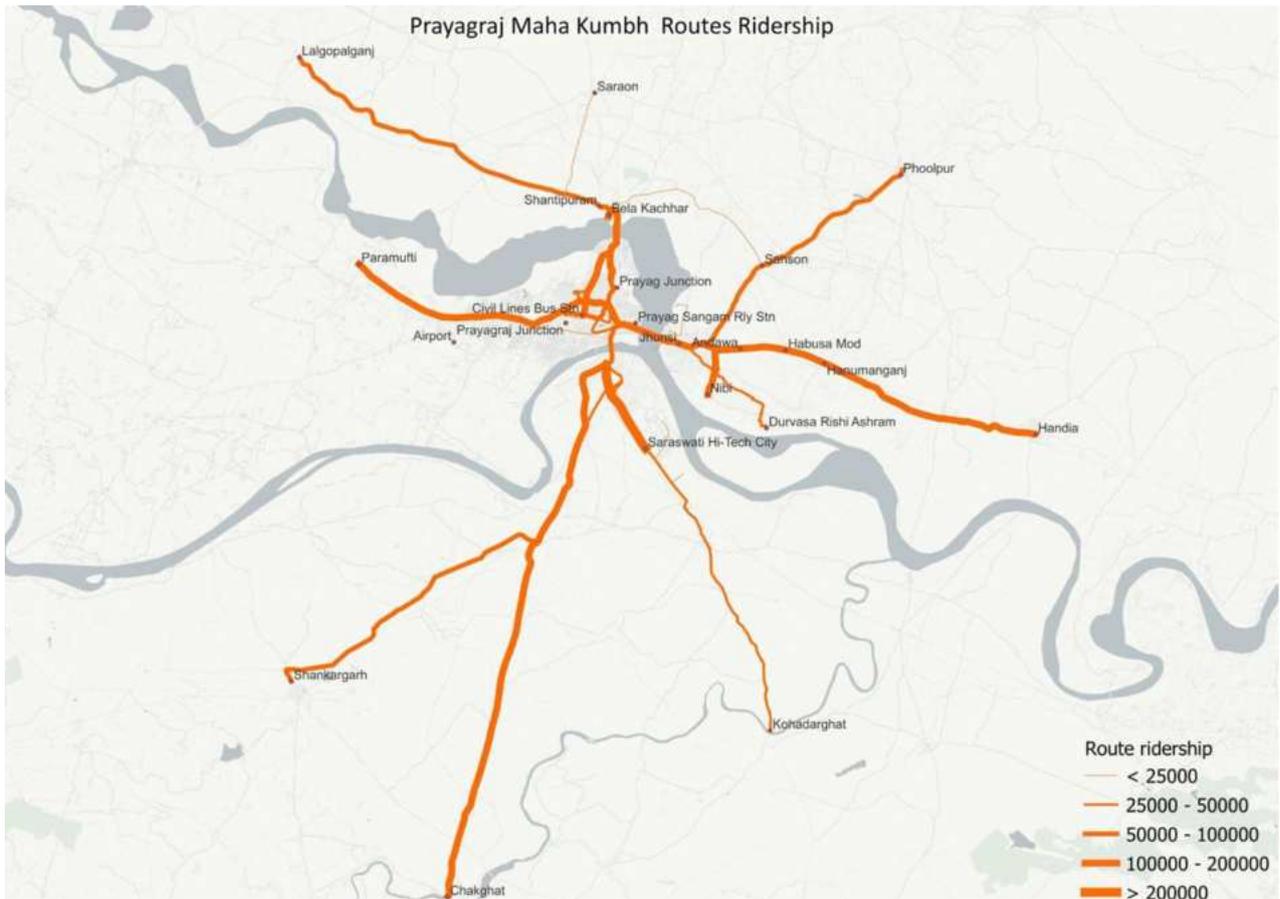
Source: CEEW analysis using data from Directorate of Urban Transport and Prayagraj City Transport Service Limited

Table 26. Prayagraj Maha Kumbh charging infrastructure and depot planning

Depot name	Number of buses	Number of chargers	Type of charger	SPV	Depot planning
Bela Kachar	50	10	Fast	Agra (40), Kanpur (10)	Traffic from Lucknow
Nehru Park	50	10	Fast	Kanpur (15), Lucknow (35)	Traffic from Kanpur Highway
Andawa depot	50	10	Fast	Kanpur (50)	Traffic from Ayodhya, Varanasi, Gorakhpur, and Bihar
Leprosy/Naini depot	50	10	Fast	Prayagraj (50)	Traffic from Chitrakoot and Madhya Pradesh

Source: Directorate of Urban Transport

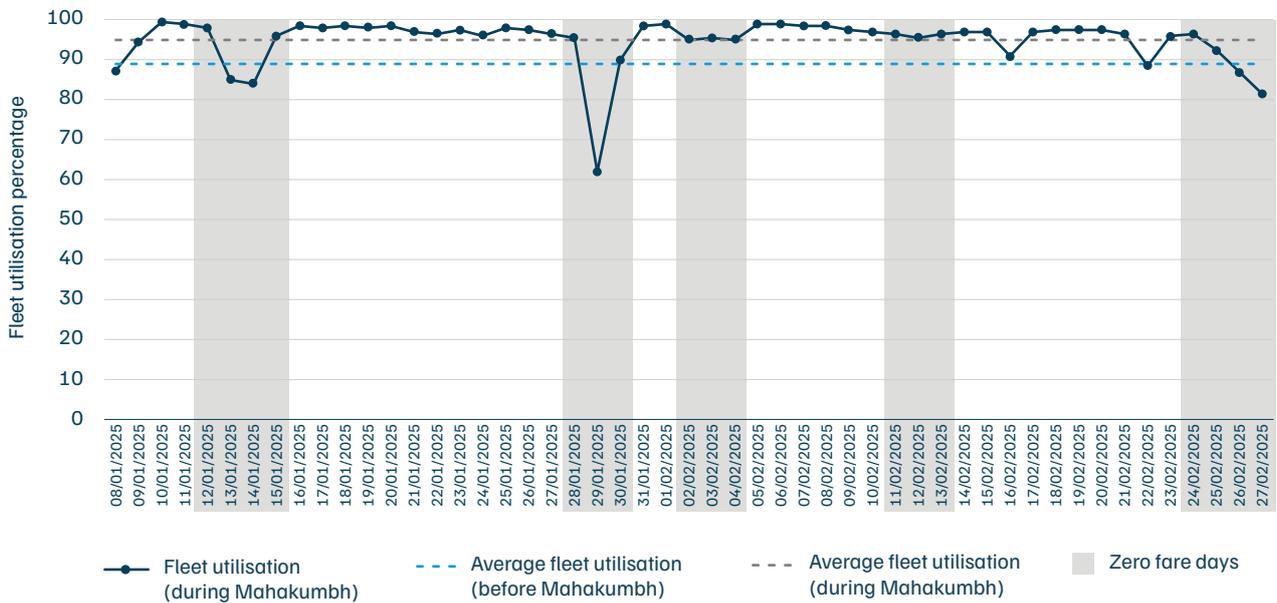
Figure 34. Over 50% passengers were concentrated on 8 ETM routes



Source: CEEW analysis using data from Directorate of Urban Transport and Prayagraj City Transport Service Limited

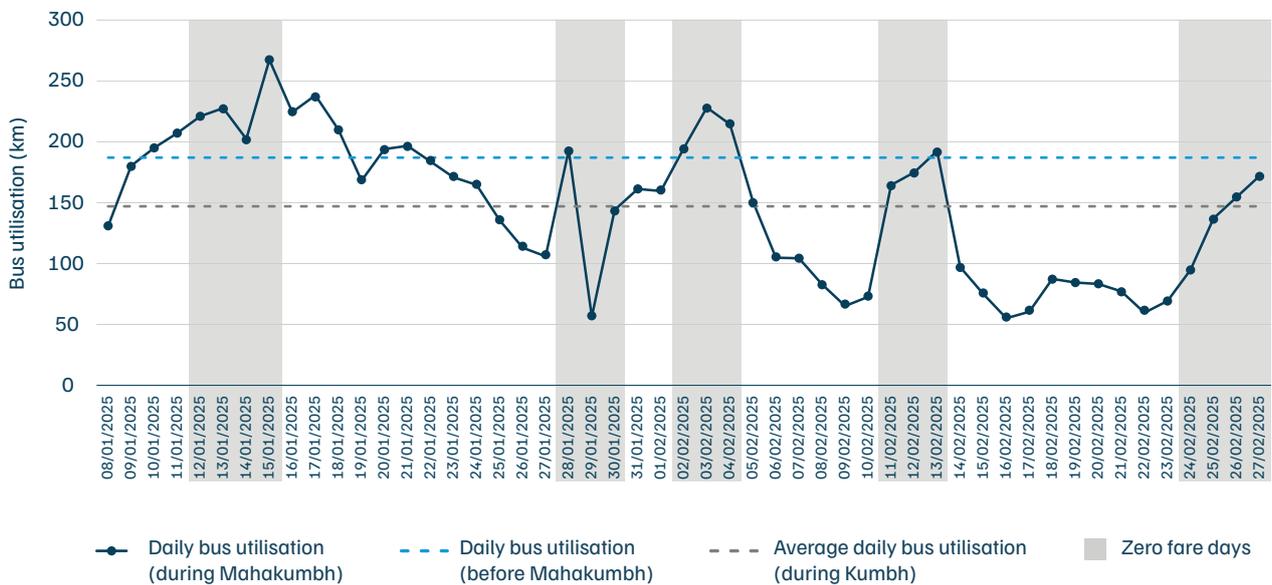
E-buses began operating for the Maha Kumbh on 8 January 2025, with a fleet uptime of over 95 per cent (Figure 35), except during the *Amrit Snan of Mauni Amavasya* (new moon on 29 January 2025), during which huge number of devotees congregated in the city, which impacted e-bus operation. E-buses operated on a total of 43 ETM routes. Out of this, 8 key routes accommodated 50% of total passengers. These routes linked major halt points (Chakghat, Jhunsi, Paramufti, Bela Kachhar) on the city periphery to the Sangam area.

Figure 35. Fleet utilisation stayed consistently above 95% during the Mela period, except on some zero-fare days due to high pilgrim rush



Source: CEEW analysis using data from Directorate of Urban Transport and Prayagraj City Transport Service Limited

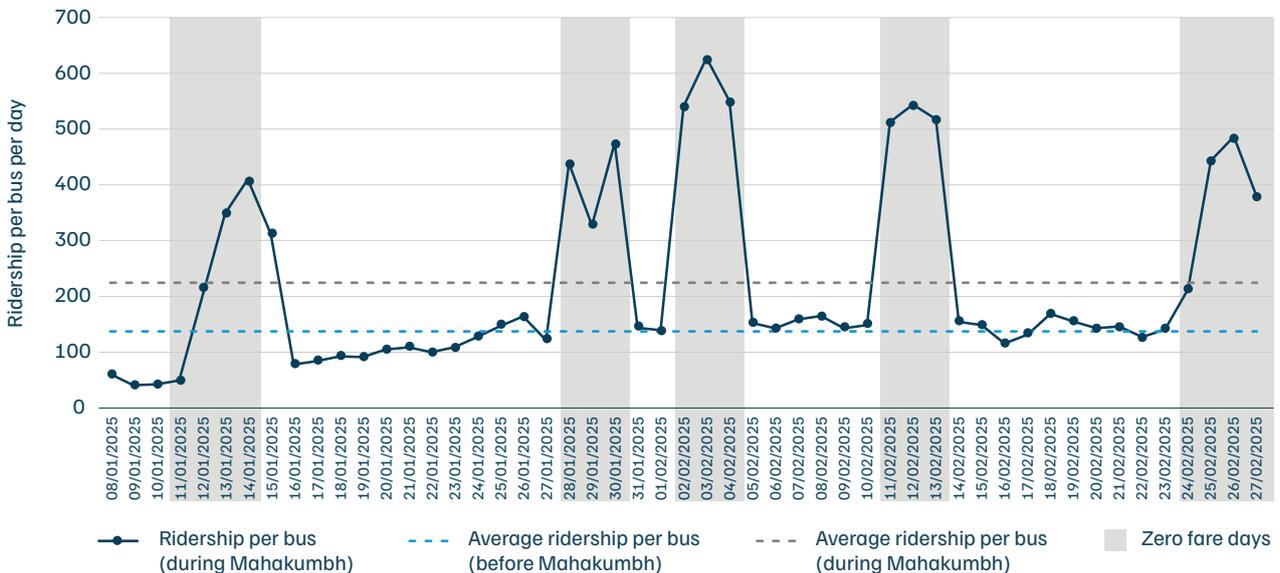
Figure 36. Bus utilisation during the Maha Kumbh was lower than pre-Kumbh levels, primarily due to increased pilgrim rush



Source: CEEW analysis using data from Directorate of Urban Transport and Prayagraj City Transport Service Limited

Operating from 8 January onwards, 200 e-buses consistently completed 1.48 million (14.8 lakh) km or more as per ETM records, making the average bus utilisation 147 km per bus per day during the Maha Kumbh. Also, the maximum bus utilisation crossed 250 km on 15 January 2025 (Figure 36), which has rarely been achieved since the launch of these e-buses in UP. Congestion, in fact, led to the under-utilisation of buses. More than 2.1 million (21 lakh) people travelled in shuttle e-buses (Figure 37). Based on field visits and expert insights, actual ridership is estimated at ~400 passengers per bus per day, compared to the recorded 224—this is likely underreported due to overcrowding which caused difficulty in ticketing. Further, shuttle e-buses operated with zero fare on *Snan* days, as well as the day before and after. A major spike in ridership—approximately 60 per cent of the total ridership—was recorded during these days (*Amrit Snan* days with zero fare). SPV-wise ridership shows that buses of Agra SPV ferried the most passengers (0.62 million), followed by Kanpur (0.6 million), Prayagraj (0.53 million), and Lucknow (0.37 million) (approximate figures). A maximum of only four buses faced minor breakdowns on any particular day, with an average daily breakdown rate of 3.5 buses per day.

Figure 37. Average ridership during *Amrit snan* days was recorded to be 2 - 3 times higher than the average ridership during the Kumbh



Source: CEEW analysis using data from Directorate of Urban Transport and Prayagraj City Transport Service Limited

During the Maha Kumbh, the operation of e-buses presented both challenges and benefits for both its users and staff. Given the overwhelming number of pilgrims from diverse backgrounds, managing smooth operations from 5 a.m. to 10 p.m. was a demanding task for the staff. The staff was well-trained and managed to provide a seamless service and convenience to passengers despite the crowds. On interacting with pilgrims who had used the e-buses, we learnt that the e-buses had offered a cost-effective alternative, as private operators had charged super-high fares for e-rickshaws and two-wheelers, making them unaffordable. The air-conditioned buses with comfortable seating provided a much-needed respite from the congestion and chaos; however, overcrowding remained an issue due to the high demand.

Table 27. Emissions averted with e-buses during the Mahakumbh

Emission type	Operated kms	Emission per km	Total emissions averted (in kgs)
PM	14,80,371	0.0172	25.5
NOx		0.7908	1170.7
CO		4.7273	6998.8

Emission factor source: Automotive Research Association of India (ARAI)

E-bus operations during the Mahakumbh resulted in fuel savings of about 3.7 lakh litres of diesel (at fuel efficiency of 4 km per litres), leading to substantial financial and environmental benefits. The shift to e-buses helped avert about 26 kgs of PM, 1171 kgs of NOx and 7000 kgs of CO.

Stated challenges

Despite the smooth completion of the herculean task of operating buses at the Prayagraj Maha Kumbh, officials, staff, and passengers of e-buses stated the following challenges:

- **Managing operations in extreme crowd conditions:** The huge volume of pilgrims during the Maha Kumbh led to overcrowding and delays, and even route curtailment, to manage crowds during peak hours.
- **Diversity of passengers:** The influx of people from different backgrounds and regions made it difficult to cater to all passengers, as it created an inevitable language barrier between the pilgrims and the staff, with the latter knowing only Awadhi, Hindi, and Bhojpuri.
- **E-bus SOC:** E-buses are strictly mandated to maintain their SOC above 20 per cent. However, to streamline the flow of pilgrims, the main roads were barricaded and buses were diverted, leading to SOC's below 20 per cent; a case of 0 per cent SOC, causing battery damage, was also reported.
- **Staff management:** Limited available resources in Prayagraj led to temporary relocation of staff from 3 SPVs. They were also asked to serve over times. This relocation of staff and their management was a challenge.



5. Conclusion

Buses remain a critical mode of transport across the country, providing access to jobs, education, healthcare, and recreation venues. Most buses (over 50 per cent) are deployed for school, staff, and public transport-related services. CEEW's TTFM model predicts that by 2047, around 3.34 million (33.4 lakh) buses will be on-road. In a BAU scenario, it estimates that 42 per cent of new sales of buses will be electric and that about 30 per cent of the on-road stock will be electric in 2047.

With the introduction of national schemes like the PM e-Bus Sewa scheme, the intra-city e-bus sector has grown over the past decade. The projected annual supply of over 40,000 e-buses highlights that India's e-bus market is poised for rapid expansion. The study finds that bus manufacturing and its operations will create annual total jobs to the tune of about 5.14 million (51.4 lakh) jobs by 2030 and 10.11 million (1.01 crore) jobs by 2047. Thus, e-buses are bound to bring sweeping changes across the bus sector. However, it is crucial to understand the key characteristics, learnings, and issues of early e-bus initiatives.

5.1 Key challenges and learnings from case studies

- **E-buses are cost-prohibitive** for upcoming CTUs due to their high capital costs, exacerbated by charging and range limitations. Schemes like FAME II and *PM e-Bus Sewa* can help address the issues using GCC models, but the eligibility-based distribution of subsidy and the sunset clause imply that scale-up is limited. Here, Guwahati's new contractual model, the 'fixed-cost operating model' of utilising *Smart Cities* funds to procure e-buses can assist aspirational cities in ramping up their **public transport**.

Box 3. Guwahati's fixed-cost operating model

By implementing a fixed-revenue structure, ASTC ensures profitability for itself, including third-party operators. The fixed-revenue model of operation was made possible as the e-buses were procured using the Guwahati Smart City Fund, making the capital costs competitive for ASTC. To materialise the revenue, the operators pay fixed standing and running charges to ASTC, which guarantees a stable income of around INR 75 lakh per month without any burden of e-bus operations.

Despite challenges like infrastructure demands, high operational costs, and occasional schedule disruptions, the city authority can successfully make an earning of INR 9 crore annually, which can break even in 10 years while providing efficient public transport services.

- **E-bus uptake has been limited to intra-city bus operations**, as most government schemes provide e-bus subsidies to public bus operating companies. However, private operators represent over 80 per cent of the bus market. Learnings from private operators highlight that with rising voluntary non-financial environment declarations under Scope 3, companies are willing to invest in e-buses for their employees' transport needs. Further, inter-city luxury e-bus services by the private operators highlight that e-bus utilisation is increasing across more use cases and operators. These new avenues, like staff and inter-city e-bus operations for businesses, have attracted private-sector investments in e-bus operations, making both an environment and business case for the involved stakeholders.

Box 4. Chartered Speed plans to electrify its entire bus fleet

Following the introduction and operation of intra-city e-buses in Indore, Chartered Speed added another set of 10 e-buses to its fleet in 2022, which operate as staff buses between GIFT City and Ahmedabad. It aims to electrify its entire bus fleet of approximately 2,000 buses in the coming years, **which is in line with the country's net-zero vision**. The transition will begin with its inter-city fleets, replacing the existing 350 diesel buses operating in B2C mode. **As part of the first phase, the company has already placed an order of 900 e-buses.**



Box 5. Veera Vahana in collaboration with SUN Mobility launches its 10.5-meter battery-swappable buses

In 2024, SUN Mobility, a key provider of swapping infrastructure, partnered with Veera Vahana to introduce the first 10.5-metre swappable buses for inter-city routes and mofussil routes in Bengaluru. Swappable-battery buses cost significantly lesser (INR 60–75 lakh per bus) than fixed-battery buses (INR 1.8 crore per bus), reducing upfront costs and encouraging commercial EV adoption.



- As observed in Gandhinagar and Surat city bus operations, **high battery replacement costs pose significant challenges for the long-term viability of e-buses**. Further, **battery degradation challenges**, as seen in Indore's and Guwahati's city e-bus operations experience, as well as e-buses' **susceptibility to breakdown during waterlogging**, highlight the technology's limitations. However, the efforts of CTUs in Prayagraj, Surat, and Indore, to decentralise charging infrastructure and optimise the charging schedule, along with learnings from battery-swapping and battery-retrofitting models, highlight that operational and technological innovations can reduce the burdens faced.

5.2 Recommendations

The study documents a series of initiatives that highlight the growing preference for e-buses among various stakeholders, including operators, industry partners, drivers, and riders. However, catapulting the technology's adoption requires coordinated efforts. Thus, we suggest a three-pronged approach to strengthen this nascent sector – more private investment, pilot projects, and robust research and development (R&D) – as explained below.

- **Facilitate mandatory data sharing on battery cycle utilisation**

E-bus batteries come with insurance coverage for battery charging cycles (ranging from 2,000–5,000 cycles) and a life-term limit (generally five years). During this tenure, batteries degrade, leading to a reduction in range, as observed in Guwahati and Indore. Cities like Indore have attempted to use an opportunity-charging strategy to tackle the range issue observed due to battery degradation, however, experts opine that these methods may exacerbate the degradation process. OEMs' reluctance to share data on charge cycle utilisation makes planning challenging for bus fleet operators. Thus, policymakers must create a regulatory framework that mandates battery data sharing; this helps create a more robust battery-insurance ecosystem and will improve the secondary market value of e-buses. Further, the government must support and fast-track the adoption of proven technologies like battery swapping and retrofitted e-buses.

- **Promote shared charging infrastructure**

While depot planning and infrastructure remain concerns for the bus sector, the charging needs of e-buses further aggravate concerns. As demonstrated by the example of Prayagraj, Surat, Ahmedabad, and Indore, – CTUs case, effective operations combined with strategic investments in charging infrastructure can help overcome range limitation issues. The *PM E-DRIVE* scheme has renewed the focus on e-buses and charging stations. **Comprehensive guidelines from the Association of State Road Transport Undertakings (ASRTU), MoRTH on shared depot charging and battery-swapping stations** for buses will help City Transport Undertakings (CTUs) and State Transport Undertakings (STUs) improve their e-bus operation efficiency.

- **Mandate niche use cases**

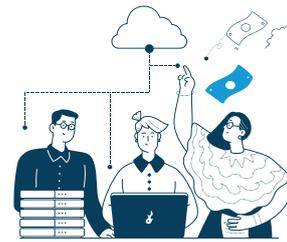
Learnings from Chartered Speed and NueGo highlight that environment-friendly e-buses have proven techno-economically viable for niche limited-range operations such as NueGo's inter-city luxury travel initiative, intra-city public transport operations, and staff transportation. Based on these findings, the government must consider **mandating e-bus usage in limited area-based operations**, such as special economic zones (SEZs), eco-sensitive or tourist zones, metro-feeder services, and airport-tarmac operations.

Way forward

This study presents learnings from India's early e-bus initiatives, highlighting how different cities have tackled key operational and technology challenges, including showcasing newer operational avenues of e-buses. It highlights innovative strategies adopted by CTUs/STUs and private players to tackle challenges like high upfront capital costs, declining battery efficiency at the end of life and high dead kilometres. The report further explores emerging operational avenues in the e-bus sector, including staff and intercity luxury buses, along with unique innovations by private players such as bus retrofitment and battery swapping.

Despite these promising developments, several challenges persist. These include limited visibility and data of battery usage, degradation and lack of preferred location land for depots, difficulties in achieving financial viability before and including battery replacement, and the scalability challenges of battery swapping and retrofitment technologies. To add to the concerns - the EVs are still a comparatively nascent sector and newer battery chemistries, and energy storage technologies are rapidly evolving. While several countries have adopted a single focus to EVs, India has adopted a multi-fuel strategy, thus only specific bus use-cases that gain substantial economic and environmental benefits are likely to transition to e-buses. Given the evolution, the sector will mature and stabilize only over the next decade.

We plan to further deep-dive in high potential use-cases over their life to document and study in detail various aspects including battery cycles, degradations, and viable financial and operational models. While documenting case study supplies adequate data and real-life situations to model, addressing these issues will require coordinated efforts from national and state governments, transit agencies, OEMs, and service providers.



Coordinated efforts, private investment, and robust data sharing can accelerate and sustain India's e-bus transition

Acronyms

AICTSL	Atal Indore City Transport Service Limited	HDV	heavy-duty vehicle
AMC	annual maintenance contract / Ahmedabad Municipal Corporation	HFCEV	hydrogen fuel cell electric vehicle
ASRTU	Association of State Road Transport Undertakings	HMC	high mobility corridor
ASTC	Assam State Transport Corporation	HPV	heavy passenger vehicle
B2B	business to business	ICCC	integrated command and control centre
B2C	business to company/customer	ICE bus	internal combustion engine bus
B2G	business to government	IDI	in-depth Interviews
BAU	business as usual	KPTL	Kalyani Powertrain Limited
BMS	battery management system	LDV	light-duty vehicle
BRTS	bus rapid transit system	LPV	light passenger Vehicle
CAGR	compound annual growth rate	MDV	medium-duty vehicle
CBS	city bus service	MHDV	medium- and heavy-duty vehicle
CESL	Convergence Energy Services Limited	MPV	medium passenger vehicle
CoE-ZET	Centre of Excellence for Zero Emission Trucking	NCC	net cost contract
CTU	city transport undertaking	NEMMP	<i>National Electric Mobility Mission Plan</i>
DGVCL	Dakshin Gujarat Vij Company Limited	OEM	original equipment manufacturer
e-bus	electric bus	PLI	<i>Product-linked Incentive</i>
EESL	energy efficiency services limited	SEZ	special economic zone
ETM	electronic ticketing machine	SLB	Service Level Benchmark
EU	European Union	SMC	Surat Municipal Corporation
EV	electric vehicle	SOC	state of charge
FAME	<i>Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles</i>	SOUADTGA	Statue of Unity Area Development and Tourism Governance Authority
FGD	focus group discussion	SPV	special purpose vehicle
FTE	full-time employment	SSL	Surat Sitalink
GCC	gross cost contract	STU	state transport undertaking
GDP	gross domestic product	TCO	total cost of ownership
GMZ	green mobility zone	TFFM	Transportation Fuel Forecasting Model
GNCTD	Government of the National Capital Territory of Delhi	VGf	viability gap funding
		ZEV	zero-emission vehicle

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Saoni is a Research Consultant in the Sustainable Mobility Team. She works on identifying global measures and strategies for electrification and formalisation in the ZET and IPT segments. Her research primarily focuses on adapting learnings from global cities within the Indian context to formalise informal, semi-formal micro buses, and IPT systems.



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Image: CEEW

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