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THE ROAD AHEAD FOR PRIVATE ELECTRIC BUSES IN INDIA:
Case of Non-urban Routes

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THE ROAD AHEAD FOR PRIVATE ELECTRIC BUSES IN INDIA :
Case of Non Urban Routes

Report | February 2024

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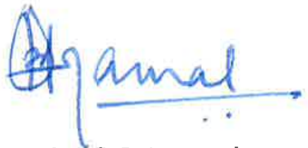
FOREWORD

India has embarked on a momentous journey to electrify its mobility services. This is to not just meet its global commitments but also to play a pivotal role in global emission reduction. As a part of this endeavour national programs such as the FAME 1, FAME 2 and PM e-Bus Sewa, under the leadership of honorable Prime Minister of India, Shri Narendra Modi ji, has given us a head start in electrifying the fleet of buses in India.

Buses are the backbone of road-based mobility in the country. About 2.3 million registered buses operate as stage carriage and contract carriage services and as transport and non-transport or staff vehicles. These are operated both by public and private operators. Approximately 88 per cent of these buses are devoted to non-urban or inter-city/regional services. Almost three-fourth of these, are operated by private operators. They contribute to more than 55 per cent of all emissions by buses in the country and consume substantial oil. Both energy security and green house gas (GHG) reduction commitments by Government of India can be partially met with electrification of these services.

In this context, the report explores the potential bottlenecks in achieving electrification of non-urban stage carriage buses in India. It specifically focuses on private operations of electric buses, to understand their financial viability for operators. However, ecosystem and financing barriers in transitioning to electric buses exist.

This report provides policy makers with a unique insight on necessary levers to unlock local and international financial opportunities for electric bus operations. It is thus an important resource to help accelerate the electrification of buses in India. The report provides recommendations for overcoming these barriers to accelerate financial markets for bus electrification in the country. I trust that this document will serve as an important contributor to India's journey to emission-free mobility.



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FOREWORD

As we enter a transformative era in India's transportation landscape, the electrification of private sector buses stands out as a key driver toward achieving India's Net Zero Target by 2070. This report makes a significant contribution to our understanding of the challenges and opportunities in this crucial sector.

Private operators, representing over 92% of the bus sector in India including Urban/ Non Urban Stage Carriage, Intercity, Tourist, Staff & School Mobility play a vital role in meeting the daily transportation needs of millions. The report, covering five states, highlights the current scenario where rising fossil fuel prices are prompting private operators to reconsider their operations, given that most currently use CNG or diesel.

E-buses, with their lower cost per kilometer (CPK), offer a viable and economically advantageous option for non-urban routes. The variations in upfront costs and operational efficiencies among different Original Equipment Manufacturers (OEMs) emphasize the need for a thoughtful approach to adopting this transformative technology.

The financial planning insights, product recommendations, and regulatory considerations in the report provide a roadmap for private operators, OEMs, and financing institutions. Governments should leverage these findings to establish effective incentives, regulatory mechanisms, and policy provisions, acceleratingthe adoption of e-buses among private operators.

The Bus & Car Operators Confederation of India is dedicated to fostering sustainable and innovative solutions for the private bus sector. This report serves as a valuable guide for policymakers, industry stakeholders, and operators as we collectively work toward a greener and more sustainable future for India's transportation sector.

I extend my sincere gratitude to the authors of this report for their dedicated efforts in providing insights that will undoubtedly shape the trajectory of private-sector bus electrification in India.

P.K.P

Prasanna Patwardhan
President, Bus & Car Operators Confederation of India
Chairman & Managing Director, Prasanna Purple Mobility Solutions Pvt. Ltd.

FOREWORD

In Tamil Nadu, about 70% of operations are privately owned and operated. These private buses are vital, carrying millions of passengers daily, connecting rural and urban areas, and serving as the backbone of the state's road transportation network. The transition to electric buses will facilitate a significant shift of passengers towards clean and green mobility and contribute to the broader vision of providing everyone with sustainable and affordable energy solutions. By embracing the electrification of private buses, the state can widely promote the use of clean and sustainable energy sources, reducing reliance on traditional fossil fuels.

The report recommends much-needed regulatory reforms to encourage private operators to shift to electric buses. Fiscal incentives, like direct subsidies and lower interest rates, are crucial to making electric buses financially viable, especially in the initial phase. These proposed measures align with the urgent need to speed up the adoption of electric buses among private operators.

Additionally, the report highlights the essential role of charging infrastructure in the success of private electric bus operations. Accessible and affordable charging points are necessary for the widespread use of electric buses. Proposed interventions, such as, creating a platform for private operators and encouraging green charging power-purchase agreements, are critical ecosystem measures to support private bus electrification.

Collaboration between stakeholders, regulatory bodies, and industry players is also vital for the transition. The report's recommendation to strengthen unions and cooperatives of private bus operators is a strategic move toward institutional strengthening and collective negotiation for fiscal incentives and regulatory changes.

My sincere gratitude to the authors for shedding light on these critical aspects that will shape the future of private bus electrification in our state.

D. R. Dh-[signature]

D.R. Dharmaraj
Additional Secretary, Bus & Car Operators Confederation of India
Secretary, Tamil Nadu Stage Carriage Association
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Table 1 List of Abbreviation

AMC	Annual maintenance contract
AME	Average monthly earnings
AMRUT	Atal Mission for Rejuvenation and Urban Transformation
ARAI	Automotive Research Association of India
BEE	Bureau of Energy Efficiency
BO	Battery optimisation
BS6	Bharat Stage VI
CESL	Convergence Energy Services Limited
CNG	Compressed natural gas
CPK	Cost per Km
CPO	Charge point operator
DCTSL	Dewas City Transport Services Limited
EESL	Energy Efficiency Services Limited
EPK	Earning per km
EV	Electric vehicle
FAME	Faster Adoption and Manufacturing of Electric Vehicles Scheme
FE	Fuel efficiency
FGD	Focused group discussion
GCC	Gross cost contract
GECL	Guaranteed emergency credit line
GST	Goods and services tax
ICE	Internal combustion engine
IPT	Intermediate public transport
JKSRTC	Jammu and Kashmir State Road Transport Corporation
KL	Kerala
KSBL	Kleen Smart Bus Limited
LD	Ladakh
MP	Madhya Pradesh
NBFC	Non-banking finance companies
MoRTH	Ministry of Road Transport and Highways
RTO	Regional Transport Office
SIDCO	Sindhu Infrastructure Development Corporation
SOC	State of charge
SPV	Special purpose vehicle
STA	State Transport Authority
STU	State Transport Undertaking
TCO	Total cost of ownership
TN	Tamil Nadu
UT	Union Territory
VGF	Viability Gap Funding

EXECUTIVE SUMMARY

In India, non-urban bus operations comprise 88% of all stage carriage bus services, catering to over 150 million daily passenger trips. Currently, there are 0.4 million such buses, but the demand will rise to 0.7 million buses by 2030 (MoRTH, 2019; Gandhi et al., 2021). Private operators cater tor 60% of these operations under stage carriage permits. However, we estimate that rising fossil fuel prices are pushing many operators out of business, all of whom currently ply CNG/ diesel buses.

As India looks at its 2070 net-zero targets, balancing economic growth with affordable and clean mobility is key. Here, electrification of the stage-carriage buses can present an opportunity. However, India has a negligible number of e-buses currently plying in non-urban areas, and will need 390,000 e-buses by 2030, to be on track to meet 100% electrification by 2050 (Gandhi et al., 2021). This would lead to significant reduction in emissions and catapult the decarbonisation of the sector. Our study tests the viability of e-buses in non-urban settings and documents various challenges to the transition.

We studied 22 private-operator-run intercity and mofussil routes across three states and a Union Territory to test the viability of e-buses. We gathered e-bus-related performance and technical specifications on 16 e-bus models from three Original Equipment Manufacturers (OEMs). These OEMs have a 70% market share and this data was used to build our 'e-bus viability tool'. We make assumptions in the model for charging tariffs; while permit fees, and parking fees are substituted as per the prevailing diesel bus operation conditions.

KEY FINDINGS

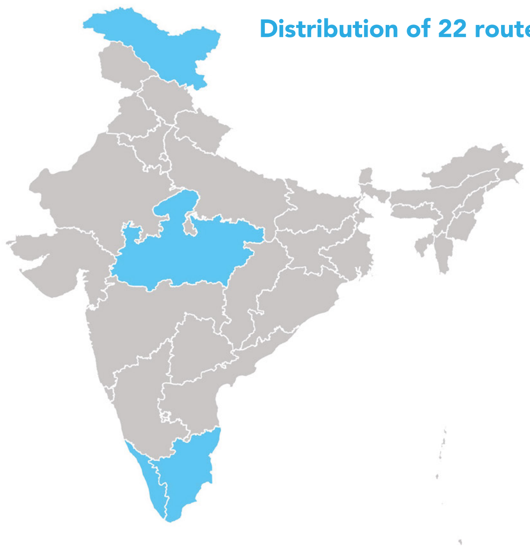
E-buses are more viable than diesel buses, due to lower cost per km (CPK) across 17 of the 22 studied routes, especially for the OEM whose upfront cost is the lowest and have the highest stated fuel efficiency (FE). We find high variation in the upfront costs and operational efficacies between different OEM models. The 9 meter (9m) e-bus models show higher profitability when replacing their commensurate diesel version (same seating capacity). 12 meter (12m) e-buses offer lower profit margins than 9m e-bus owing to 20% higher bus costs and lower FE.

Battery capacity optimisation is highly sensitive to vehicle utilisation impacting the total cost of ownership (TCO) of an e-bus. However, battery capacity **optimisation by route length** helps save time in charging and allows operators to schedule more trips. We find the following nuances in the **route length categories:**

- **Mofussil routes** (shorter than 120 km) across the plains (terrain) are profitable for 12m and 9m non-AC e-bus operations.
- **Longer routes** (greater than 120 km) are not profitable for operating e-buses if vehicle utilisation is less than 400 km per day. We find that current bus models' battery capacities are insufficient for longer route lengths.
- Both mofussil and long hilly routes are profitable for 9m e-bus operations. We find that for hilly routes, e-buses have significantly lower CPKs than diesel buses, due to downhill regenerative braking.

Non-urban e-bus operations are more profitable than diesel bus operations over the duration of the life of the bus. However, the high cost of finance remains a major deterrent to e-bus adoption. We estimate that under prevailing loan conditions, majority (>50%) of e-bus owners will face significantly more losses than diesel bus owners during the loan repayment period of 4-7 years.

Eight state EV policies provide up-front incentives for procurement of e-buses. Our analysis shows that either a 10-15% subsidy on e-bus costs or an INR 10,000-12,500 per kWh on battery sizes can reduce the burden faced during loan repayment tenure, however it has no impact on the high down-payment cost. Thus, we find that **leasing e-buses remain the most promising option.** However, we also find that the limitations of the regulatory structure for permits, concerns around charging infrastructure, customised products and skills are barriers to exploring e-bus technology.



Distribution of 22 routes studied across four geographies

State / UT	Number of Routes
Ladakh	5
Madhya Pradesh	5
Tamil Nadu	5
Kerala	7

Thus, we recommend four levers to usher e-bus adoption in the non-urban sector

Incentivise e-buses with lower rate of interest - Private stage carriage operations remain an important segment of the affordable public transport system. Subsidies or incentives can be limited with sunset clauses.

- The government must arrange e-bus loans at a lower interest rate of 4-6% for a longer tenure of 7 years, to continue its support.
- These funds can be channelled through green financing, multilateral development institutions and banks. The move will cause the least upfront burden for the exchequer, and shall help in decarbonisation of the majority of stage carriage bus sector.

Legalise permits for leasing models - The Union government must nudge the financing institutions to offer the e-bus on a leasing model, along with initial subsidies. The financers can lease buses, with insurance, maintenance and battery replacement(s), for a minimum of nine years. Although, they may require some risk-hedging mechanism. Under the arrangement, operators can bear the staff, permit and energy costs, thus sharing profits.

- However, the state government(s) must legalise transferable permits to recognise lease models where different entities may provide ownership and operations.
- Regional transport authorities (RTAs) must consider allowing different trip scheduling and an extra service operation time of 2-3 hours to compensate for time lost in opportunity charging.

Materialise affordable and accessible charging and parking - Generally, non-urban routes are longer and require fast charging at terminals, else round trips are unlikely. We find that charging costs for private operators must be capped at INR 11 per kWh to make e-bus operations viable (in comparison to diesel).

- Government must fast-track the planning, siting and erection of HDV-charging stations through power distribution companies (DisComs) or a Special Purpose Vehicle (SPV) with charge point operators (CPOs).
- Initial incentives are needed on land lease, charging equipment, or viability gap funding against the charger utilisation to attract private investment

Institutionalise private operators to convene, negotiate and upskill - E-bus technology is developing. Operators need more information, customised products, accessible after-sale services and skills for operating e-buses. The government must strengthen and recognise private operators' cooperatives or unions to create a platform.

- The platform would aggregate e-bus demands, empowered to negotiate with financing institutions, regulatory agencies, CPOs and OEMs for product designs.
- The platform would convene skilling institutions to impart the knowledge required for upskilling their crew and staff and collaborate R&D with OEMs and academic institutions.

Our findings provide e-bus financial planning for non-urban mofussil and long routes based on the **'e-bus viability tool'.** It includes product insight into required bus models and battery sizing for OEMs. Financing institutions can use these findings for developing e-bus lending portfolios and leasing contracts. These findings can support governments in establishing effective incentives, regulatory mechanisms and policy provisions to help accelerate e-bus adoption amongst private operators.

SECTION 1

NON-URBAN BUS OPERATIONS

CONTEXT

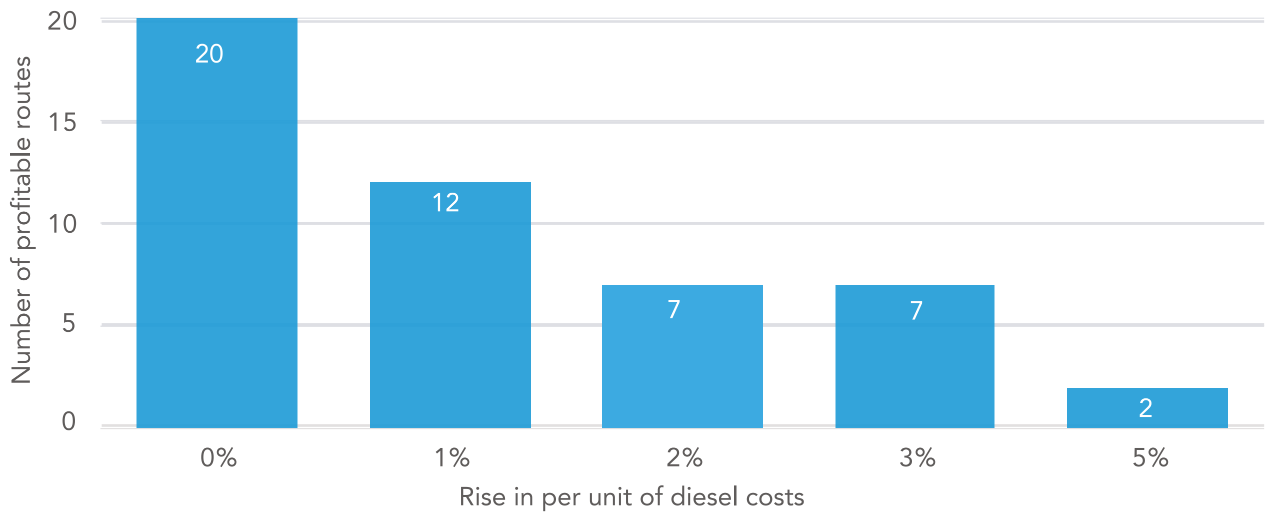
India has a fleet of nearly 2 million operational buses. Most operate as buses for private institutions (such as schools, offices, and universities) and on contract carriage. A fraction of this fleet, i.e. about 0.4 million, is dedicated to (both urban and non-urban) public transport services and is operated as stage carriage. Non-urban services constitute 88% of all stage carriage bus services in India (MoRTH 2018a; Gandhi et al. 2021). These buses cater to more than 150 million daily passenger trips and are the backbone of affordable mobility in the country. However, they are still not sufficient in numbers to cater to existing and latent demand.

There is a significant gap in the supply and demand for bus services in India (Soman, Kaur, and Ganesan 2019). Recent analysis (Gandhi et al. 2021) shows that even conservative estimates put the fleet size of non-urban stage carriage buses in India at more than 0.7 million by 2030 and over 0.9 million by 2050. A total sale of 390,000 electric buses (e-buses) are required by 2030 to put India on the path to achieve a 100% electric fleet of stage carriage buses by 2050 (Gandhi et al. 2021). To achieve this, Original Equipment Manufacturers (OEMs) will need to expand their capacity to manufacture an average of about 50,000 e-buses every year.

Just transition that is inclusive, remains a significant determinant for the Government of India. While enhancing the bus operations, it is important to safeguard the business interests of small bus operators (owning 1-9 buses) who are prevalent in offering valuable yet affordable services. The e-bus transition must create level playing fields for start-ups and traditional small-time bus operators.

NEED OF E-BUSES

Figure 1 Rising diesel costs are throwing private bus operators out of business



Source: Author's Analysis

With increasing diesel prices over the years, many currently profitable routes will soon fall below the viability threshold. Figure 1 assesses the impact of rising fuel prices on 22 routes in three Indian States and a union territory of Ladakh.

CEEW analysis (Soman et al. 2020) shows that bus-based public transport reduces vehicular emissions by four times when combined with fleet electrification. Electric buses represent the next generation of sustainable mobility, and buses will yield the highest benefits for electrification (Gadepalli, Kumar, and Nandy 2020).

E-bus adoption in India has benefited through a push from Government of India (GoI) support especially as a part of Faster Adoption of Manufacturing of Hybrid and Electric Vehicles (FAME) scheme. FAME schemes have promoted the adoption of e-buses through fiscal incentives in the form of direct subsidies. These subsidies are bundled as a part of the Gross Cost Contract (GCC) mechanism. Broadly speaking, through GCC large operators (mainly government bus operators), sub-contract operations of bus services on a per kilometre (km) payment basis to private contractors. Fare collection remains the responsibility of the public agency.

In addition to direct FAME subsidy schemes, the government is supporting price reduction through bus demand aggregation (by different State Transport Undertakings and Corporations). This is being implemented through Convergence Energy Services Limited (CESL) a wholly owned subsidiary of the state-owned Energy Efficiency Services Limited (EESL) a joint venture of public sector companies under the Ministry of Power, Government of India.

NON-URBAN PRIVATE BUS OPERATORS

Today, direct or indirect fiscal incentives by Govt only caters to State-owned bus companies.

>90%

incentives are targeted to state owned urban bus operators (Gadepalli, Kumar, and Nandy 2020).

11%

(or little over 52,000) buses are deployed on urban routes

33%

of all stage carriage buses are operated by state owned bus companies.

66%

are privately operated under State Transport Authority (STA) permit.

This means that the current central government support mechanism for e-bus adoption in India, only targets a fraction of the fleet. Without a game-plan to accelerate privately operated stage carriage buses - growth and electrification of the private bus sector will remain unaddressed. GCC is not applicable to private operators with small fleet size under stage carriage permit.
The combined emission from the public bus system in India today is estimated to be 0.2 million tCo2 per day. This is expected to double by 2030 (Gandhi et al. 2021). This underscores the need to include low and zero emission vehicles in the fleet of public services buses. Electric buses (e-bus) can play a critical role in achieving this objective.

With two-third of all public bus services being catered by the private sector, there is a need to also involve private operators actively in the electrification effort. Non-urban operations offer a higher TCO saving with electrification than for urban operations (Vijaykumar et al. 2021). It is also interesting to note since the beginning of FAME schemes in 2015 battery cost has come down by 50%, while the diesel cost has more than doubled. This means that the TCO of electric buses today is even more attractive, in comparison to ICE buses (Vijaykumar et al. 2021; Gandhi et al. 2021).

STUDY PURPOSE

Even with FAME subsidies, both private and public bus operators have thus far shown no enthusiasm to invest in electric buses, especially for non-urban operations. This is mainly because viability of e-bus operations on non-urban routes is not yet established.

We suspect apart from the general hesitation to adopt a relatively nascent technology; the key reasons could include range anxiety, cost of the electric bus, costly finance, limited charging-related infrastructure, limited service network and lack of suitable vehicle models to meet specific operational or service requirements. Clearly, the reasons for the lack of interest by operators in non-urban electric bus operations need further investigation.

A recent study (UITP 2022) assesses three regional State Transport Undertakings (STUs) using TCO comparison for diesel and electric buses and financial assessments for the e-bus transition. It summarises that e-buses are already cheaper than diesel buses on a TCO basis for 350 km/day vehicle utilisation. This is even when the costs of diesel buses can be 1/4th of similar e-bus models. It estimates that adopting e-buses through a GCC model - STUs would reduce the TCO to INR 60.6 per km, compared to INR 65.5 per km for a diesel bus (over the service life of 12 years for a bus). It shows that the dry lease model has the highest TCO as compared to GCC and owned/operated models.

UITP (2022), study recommends the VGF model and leverages steady capital through national financial instruments, payment guarantee mechanisms, and financing corporations. It highlights that capital costs and cost of financing constitute 44%-52% of the e-bus TCO for STUs in Karnataka (of which financing costs can make up 23%-34%). Increasing the debt to equity ratio, increasing loan tenure and or decreasing the interest rates are suggested to be key strategies to manage high cost of financing.

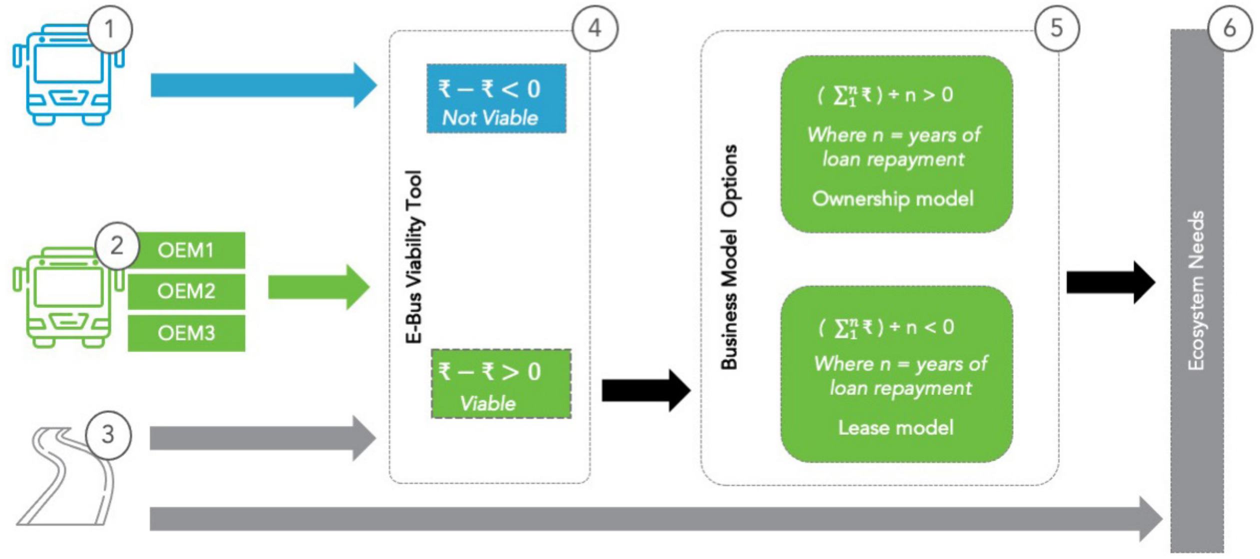
UITP study had the objective of developing fleet level TCOs for regional operations of 3 Government STUs in a state. It uses an assumption of 350 km average utilisation of all buses across fleets and compares TCOs for a standard INR 1.5 crore non-AC e-bus of a 320 kWh battery pack and contrasts it with a BS6 diesel model. This study uses an ICCT-UITP model for estimating TCO for an existing standard e-bus.

Building on the insights from the literature mentioned above, the objectives of our study are –

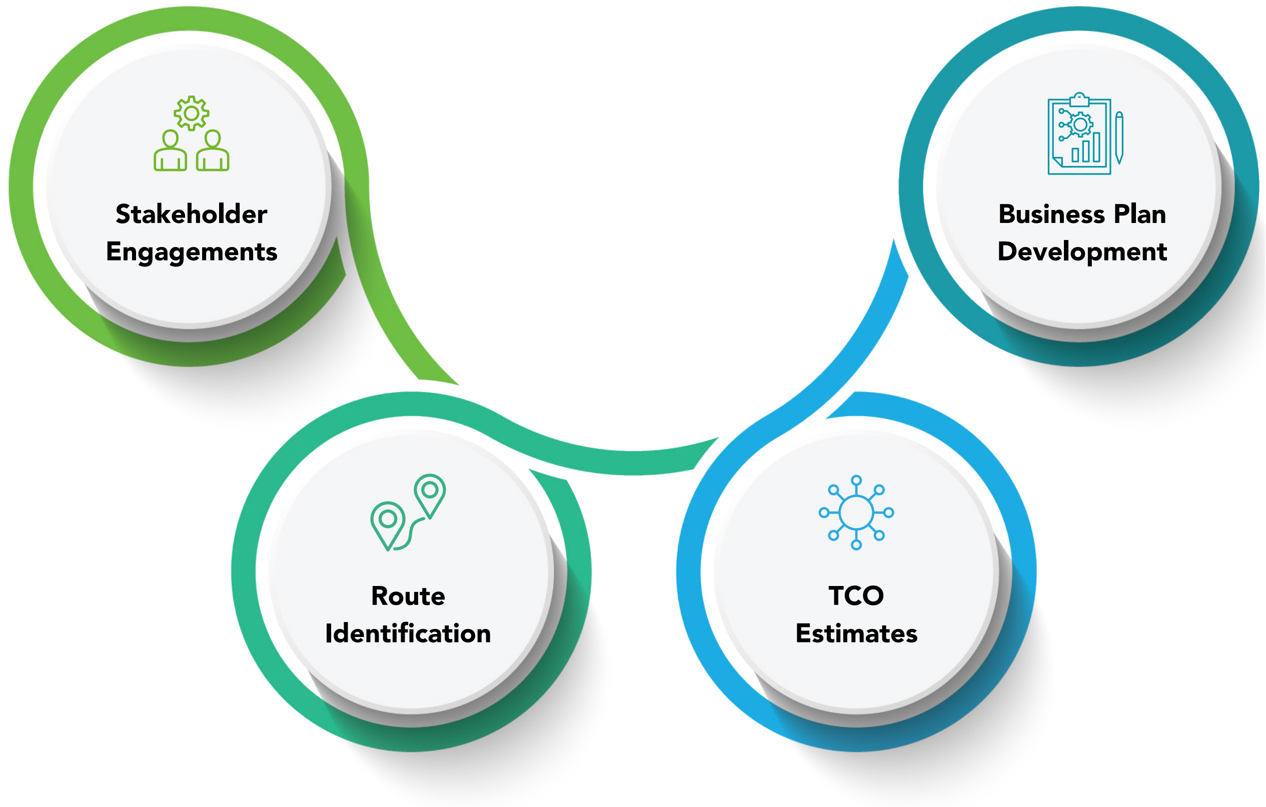
- To investigate the reasons for lack of interest in electrification of non-urban stage-carriage bus operations, especially by private operators.
- To understand the economics for electrification of non-urban bus routes operated by private entities, under State Transport Authority Permits.
- To qualitatively explore other contributing factors like state regulations, political interests etc that influences the e-bus decisions amongst private operators.
- To explore potential business models of electric bus operations for non-urban services.

STUDY APPROACH AND METHODOLOGY

Figure 2 Methodology for establishing viability of e-bus operations



1. Gather current bus costs, specifications and interest rates
2. Identify equivalent models available from different OEMs (gather specifications and costs of those e-bus models)
3. Add route-level operational and cost inputs (staff, permit, parking etc.)
4. Model Profits from EPK and CPK for both diesel and e-buses separately, and compare profits to establish the viability
5. Select preferable business model
6. Identify the ecosystem needs for your preferred model



The study uses a diverse geography approach by analysing different terrains of Ladakh (LD), Madhya Pradesh (MP), Tamil Nadu (TN), and Kerala (KL). Thus, it covers a mix of 22 non-urban areas with plains and hilly routes, ranging from 20 km to 246 km. Descriptive analysis of these routes is presented in the next chapter.

Stakeholder engagements - Study relies on rich interactions and data shared by the two set of stakeholders –

- OEMs – for bus model details, performance functions, costs, specifications etc. Detailed data on a total of 16 (8 AC and 8 non AC) products has been collected from three manufacturers - PMI Foton, Olectra and Tata Motors. Additional information on specifications and costs for both on-grid and off-grid charging infrastructure has been collected from Tata Power.
- Operators – for route details, operation details, financial details and perceptions on state level regulatory nuance and other influences.

Route Identification – Interactions with the operators have been used to gather information on a bouquet of potential routes for electrification in each geography. The project team uses an evaluation system for shortlisting 5-7 routes in each geography. This was based on weighted parameters of - high demand /ridership /frequency, permissible route lengths, stakeholder interests, connectivity, national importance, overlapping routes, etc.

TCO estimates - Authors improve an existing bus TCO model developed/published by CEEW (Soman et al. 2020). It also integrates a more recent operational parameters-based model developed by SGA. The authors discuss detailed assumptions, models and scenarios in the next chapter.

Business Plan Development – The available E-bus models have been used to put together a potential business plan for each of the identified routes in each geography in an outright purchase (and not GCC) format. The earnings per passenger km are considered fixed and suitable business models are developed in discussions with operators, OEMs, financing bodies and government stakeholders.

SECTION 2

ECONOMICS OF E-BUS OPERATIONS

We develop an **'e-bus viability tool',** that uses data from 22 routes from a total of 19 operators, in four geographies. Of these 18 were private operators, and one was public operator (KSRTC - through SIDCO in Ladakh). For each route, its operational and vehicle-specific inputs (of diesel bus) are gathered from their respective operators. All these routes are operated on an outright purchase model by the operators.

Inputs include OEMs shared data of AC, non-AC type 1 (urban operation) buses only. Unfortunately, data for none of type 2 (non-urban, intercity long route) bus models are commercially available. The bus models are classified as 7m for <8.5m length, 9m for 8.5m - 10.5m length and 12m for >10.5m length. The stated cost of these buses with batteries and GST are input in the model (Annexure 1).

OEMs claim to provide battery capacity customization on larger order sizes. However, very little data on possible sizing is available in the public domain. Thus, we model the route level energy consumption on the stated battery capacity and efficiency while considering the occupancy variation. This model estimates energy consumption initially for empty buses and adds additional estimates from literature (Liu et al. 2019) to account for passenger weight at different occupancy levels. The stated battery cycles vary between 2000 - 5000 cycles across OEMs. As all three OEMs use (NMC/LFP) battery chemistry, using (Andherson 2017) model to calculate the battery cycles for each operational scenario on each route based on the depth of discharge at charging.

In the absence of data and inputs, we made various assumptions in discussions with industry experts (refer table 2). These include seating capacity, charging costs and service and maintenance costs. Buses on non-urban routes require higher seating and lower standing capacity. Thus, the capacity of e-buses for non-urban routes (type 2 and 3 buses) should be at par with that available in the current ICE variants. We match seating capacity to the nearest e-bus model and update the corresponding earnings, while maintaining the current occupancy levels. For example, we replace an 11m diesel bus with seating capacity of 41 seats with a 40 seater 9m e-bus. For the 12m, 9m, and 7m models, the seating capacity was fixed at 50, 40, and 30 seats, respectively.

Table 2 List of Assumptions

Bus category	7m	9m	12m	Unit
Servicing, maintenance, insurance, tyre change, etc. including GST (Annual Cost)	3,00,000	3,25,000	3,50,000	INR
Seat Capacity for Type 2 bus model	30	40	50	PAX.
Cost of Charging (assuming INR 2 is taken by the charge point operator)	9	9	9	INR/ kW

Source: Author's compilation

(Li et al. 2016) suggests battery optimisation is sensitive to multiple operational factors, namely, driver attitude, traffic conditions, vehicle utilisation, route length, ambient temperature, and terrain. Due to lack of input data, the model could not include factors like driving cycle, terrain, and ambient temperature. Furthermore, as battery chemistries and efficacies evolve a more nuanced model shall be needed. We propose that real-world pilots (capturing SOC and driving cycle) are required to fine-tune the proposed methodology.

Our interviews show that most operators currently operating 12m diesel buses opt for second-hand buses. These buses are modified to accommodate additional seating capacity and cost between INR 22 - 26 lakhs. The stated cost of the new 11m diesel bus is said to be INR 40 lakhs and that of 9 m diesel buses ranges from INR 26 - 43.5 lakhs.

The routes vary in length (20 km - 246 km) and frequency of operations (1 - 12 Trips per day). 17 routes cover distances less than 120 km, a typical route length criterion for mofussil routes. Permit conditions, staff rates, strength and terminal charges vary by geography. MoRTH (2018b) exempts permit costs or battery-operated vehicles. Envisaging a mature market scenario, we model e-buses under the same route and operational parameters. Thus, we keep staff, permit, and parking charges constant even when switching to e-buses. Descriptive route data inputs are presented in Annexure 2.

2.1 VIABILITY OF E-BUSES

We define viability as the difference in profits between e-bus operations and diesel bus operations on the same route. To understand the viability of e-bus models on current routes, we model cost per km (CPKs) or total cost of ownership (TCOs) of all non-AC e-bus variants in lifecycle terms. For a particular route, we use the stated constant occupancy percentage and earnings per passenger per km as input for accounting for the variations between diesel and e-bus. We calculate and compare profits in INR per km across bus types. Annexure 2 highlights the ranges of route-level inputs used in our analytic model.

Our analysis shows that the median of profits across 14 routes for 9m e-buses are higher than current diesel buses. For most routes, e-bus models in the 12m category are less profitable (Figure 3). While the only route (in the study) with a 7m e-bus is not profitable.

Intuitively, 12m buses usually have 10-15 seats more than a 9m bus. Thus, increased per km earnings from passenger fare in bigger buses must offset its high capital cost and energy consumption (due to increased weight). However, this is not the case in the modelled routes. We elaborate on the cause for this in the next section.

2.2 PROFITABILITY ACROSS OEM MODELS

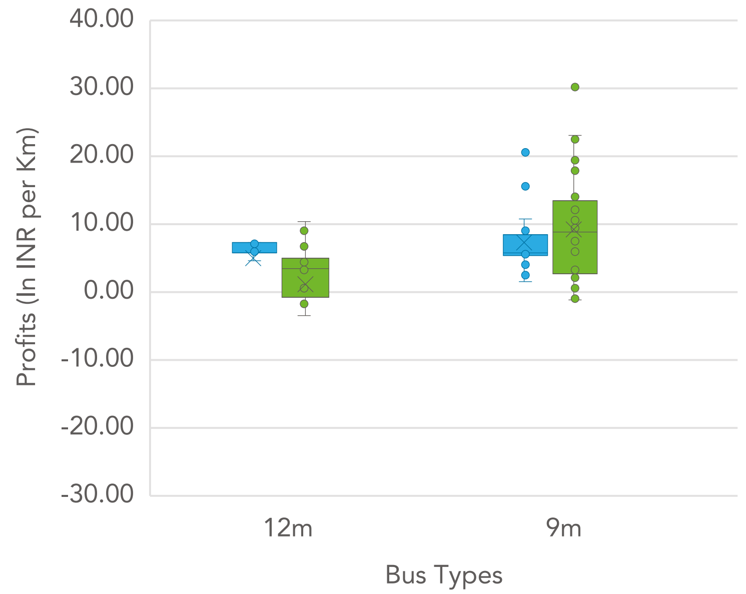
When distributed across OEMs, we find that models from one OEM are viable on 21 of the 24 modelled non-AC routes, including the 12m routes (refer to figure 4). The viability of this OEM model is mainly due to its 15% lower capital and at least 20% higher fuel efficiency than others. Thus, even in a nascent market today, we have suitable e-bus models that are viable for non-urban operations. To capture the variation in TCOs across 12m and 9m, diesel and e-bus models by OEMs, refer to figures in annexure 3.

We find that the capital cost of e-bus models varies by over 30% amongst the OEMs (figure 5). The variations can be attributed to the difference in stated battery capacities, difference in amount and quality of steel used and its fabrication process. However, the OEM 2 has the largest market share of e-buses, owing to its competitive capital cost and highest FE.

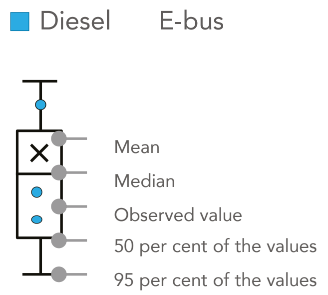
We studied the e-bus models and their associated cost components on one route (Aluva – Kothamangalam) (figure 6). We compute the total cost of ownership (TCO) across the life cycle (in INR per km) for bus-tech and OEM models. TCO and CPK mean the same in this report, and we use them interchangeably. The fuel efficiency of the buses stated by the OEMs influences both fuel and battery replacement costs. Thus, we infer that the e-bus market is yet to reach parity for costs and technology specification amongst OEMs and their e-bus models. Alternatively, we also confer that the operation (Opex) and capital costs (Capex) of an e-bus are susceptible to fuel efficiency and battery size and replacements if the rest of the factors are kept constant (Figure 6).

Switching to 9M e-buses is a profitable preposition

Figure 3 Viability across e-bus types



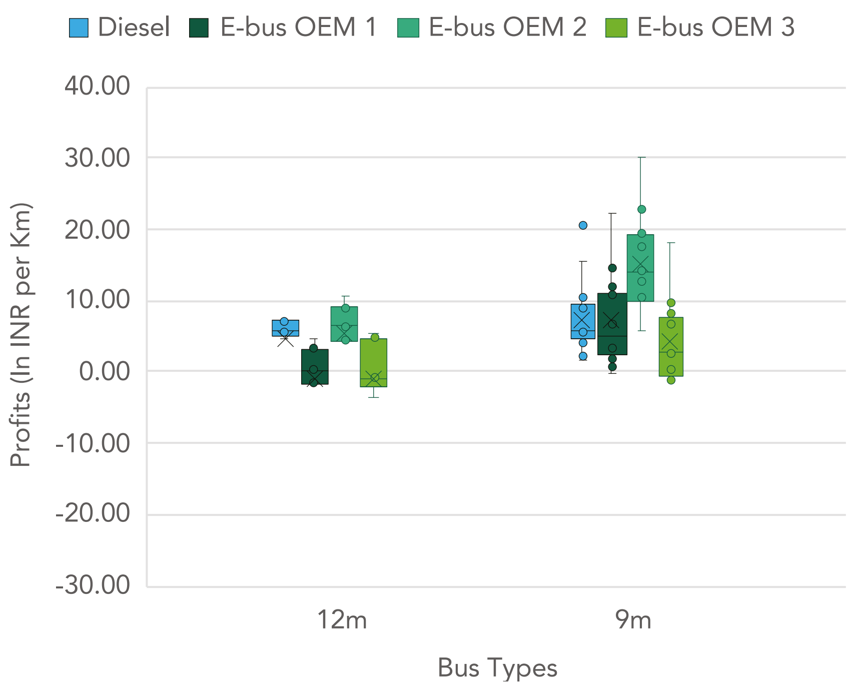
Code	Bus Type	E-bus sizes	N
12m	12 m non AC	> 10.5 m	8
9m	9 m non AC	8.5 -10.5 m	13



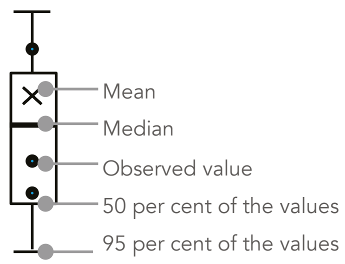
Source: Author's Analysis

One OEM offers e-bus models that are profitable across 87 % of the sampled routes

Figure 4 Viability of e-bus models across OEMs

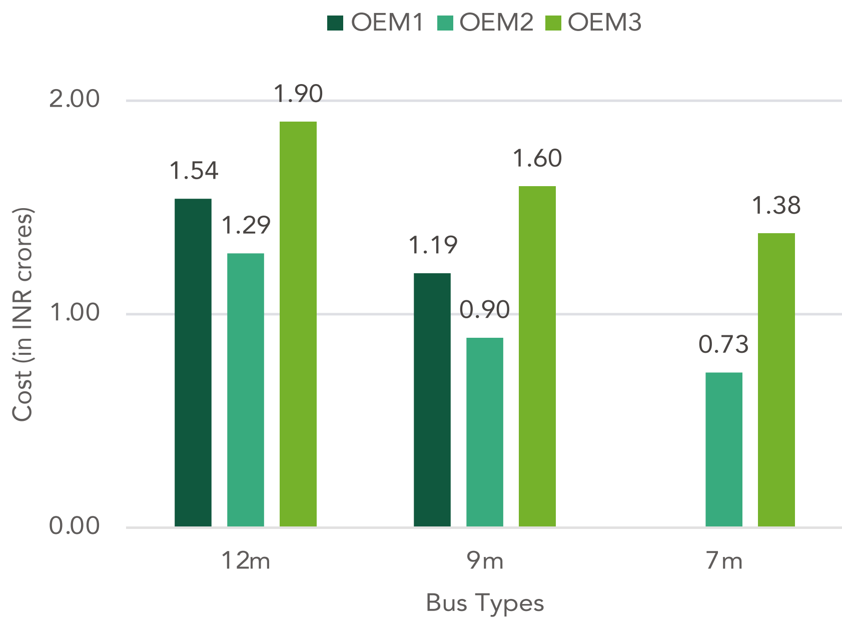


E bus size	OEM 1	OEM 2	OEM 3
Battery Capacity (Stated in kW)			
12m	265	200	268
9m	177	150	199
7m	-	102	153
Fuel Efficiency (Stated in kWh/ km)			
12m	1.11	0.80	0.92
9m	0.84	0.60	0.75
7m	-	0.50	0.72



Source: Author's Analysis

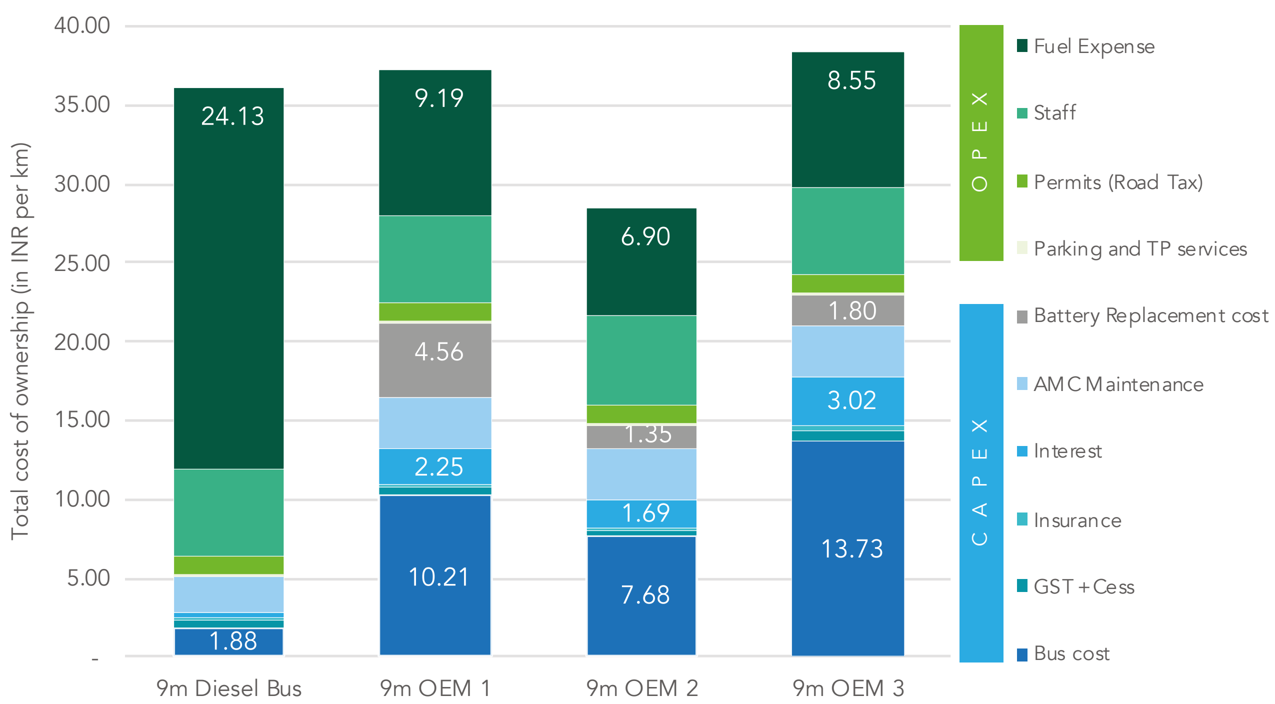
Figure 5 Cost of e-bus models across OEMs



E bus size	OEM 1	OEM 2	OEM 3
Battery Capacity (Stated in kW)			
12m	265	200	268
9m	177	150	199
7m	-	102	153
Fuel Efficiency (Stated in kWh/ km)			
12m	1.11	0.80	0.92
9m	0.84	0.60	0.75
7m	-	0.50	0.72

Source: OEMs

Figure 6 Capex and Opex costs vary across e-bus OEMs



Source: Author's Analysis (route analysed Aluva - Kothamanglam (Via Perumbavoor)

E-bus model costs and energy efficiencies vary over 30% across different OEMs

2.3 FACTORS THAT INFLUENCE THE TCOS OF AN E-BUS

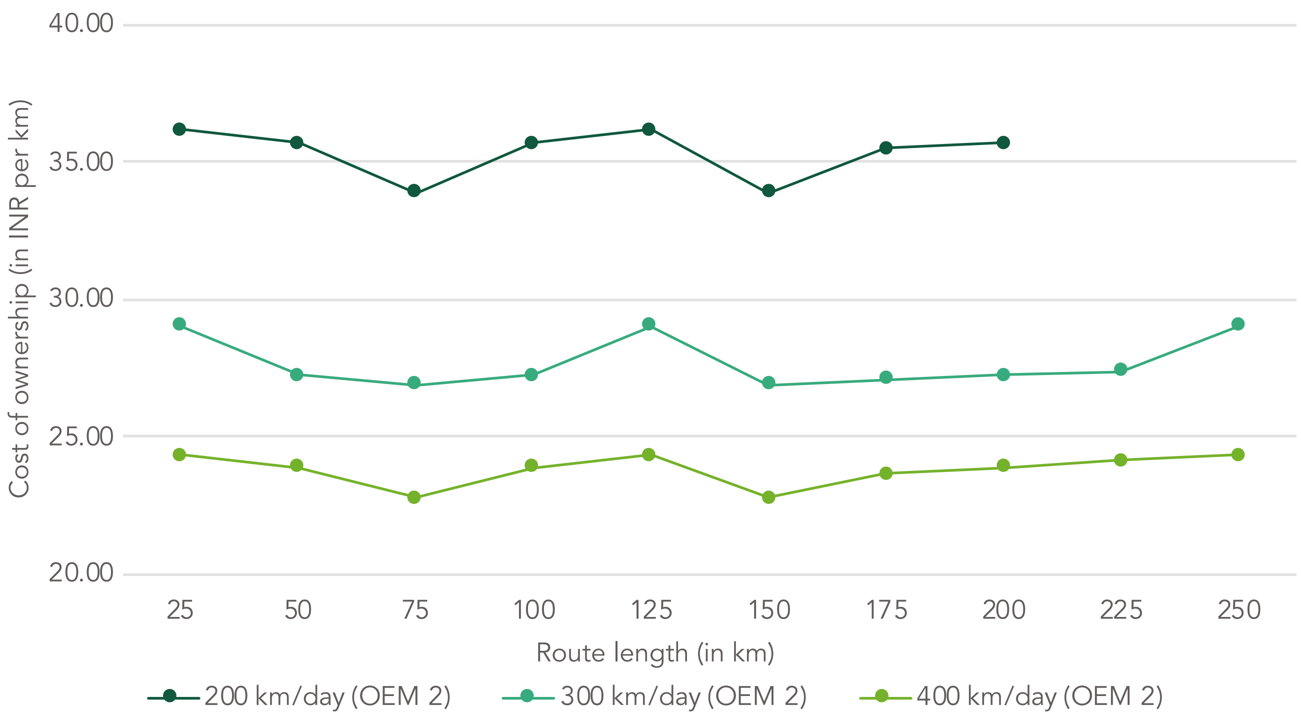
We study one bus-type model across OEMs in detail to understand the variation in TCOs across routes. Less efficient batteries would result in a relatively high depth of discharge or increased charging cycles over the same route length (Anderson 2017). The SOC of the battery determines the permissible range (route length) and the charging cycles for a battery, thus influencing the battery replacement requirements. Li et al. (2016) finds battery optimisation is sensitive to multiple operational factors. Hence, we model scenarios to determine the impact of vehicle utilisation, occupancy, and route length in the TCO of an e-bus model.

We find that for any given e-bus, the TCO varies according to the route length and vehicle utilisation, as they have a non-linear relation to SOC (figure 7). Our analysis shows that TCO remains stable with variation of +/- INR 2 per km depending on the route length. We observe that the TCOs drop as the utilisation of the vehicle increases.

Furthermore, the SOC consumption also influences the charging time required for an E-bus operation (figure 8). We find that the charging time required per day doubles with doubling of the per day utilisation. Minimising layover time for opportunity charging needs, maximises the number of trips. Hence, fast-charging infrastructure is crucial for non-urban operations.

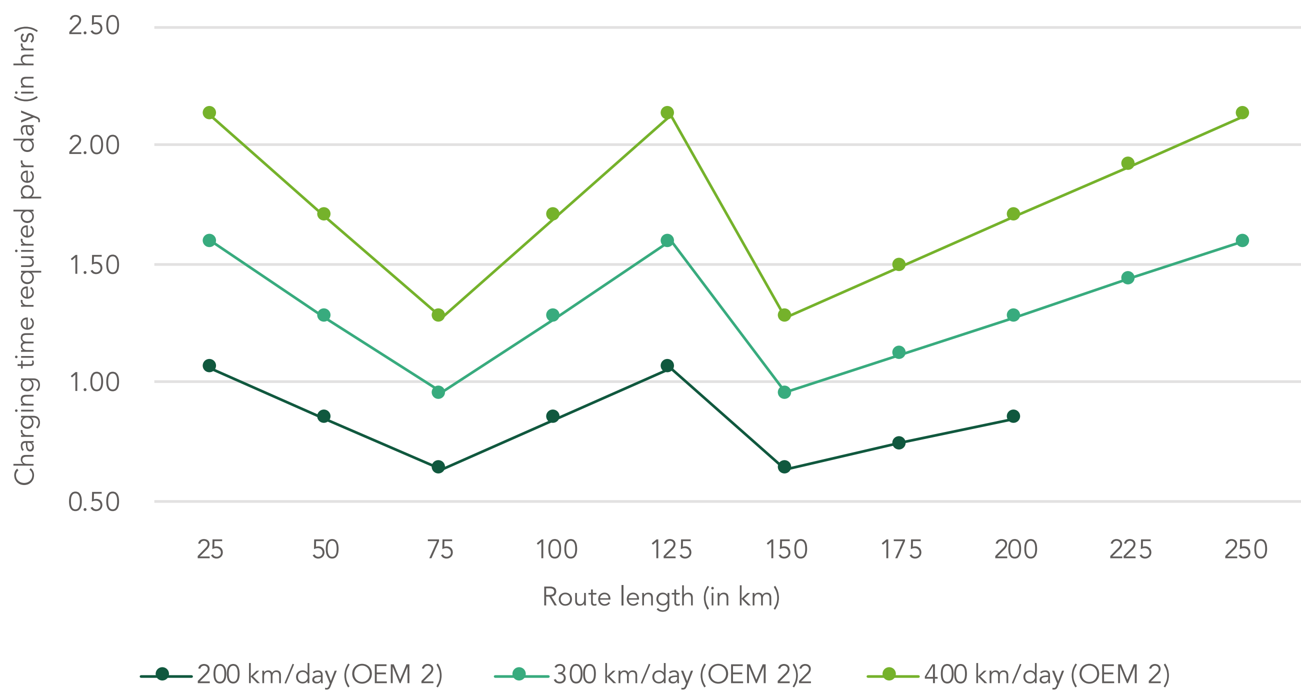
We analyse the charging time required for one charging event (cycle) with a standard DC fast charger capacity of 200 Kw per h and charger efficiency of 90%. Under the modelled condition, charging systems (chargers and the bus battery) are providing a rate of charge which achieves 95% SoC from 20% SoC in under 40 minutes for a 150 kWh battery. And 20% - 95% SoC for a 260 kWh battery in under 70 minutes.

Figure 7 E-bus TCOs are sensitive to utilisation



Source: Author's Analysis

Figure 8 Battery optimisation influences the operational schedule of e-bus fleets



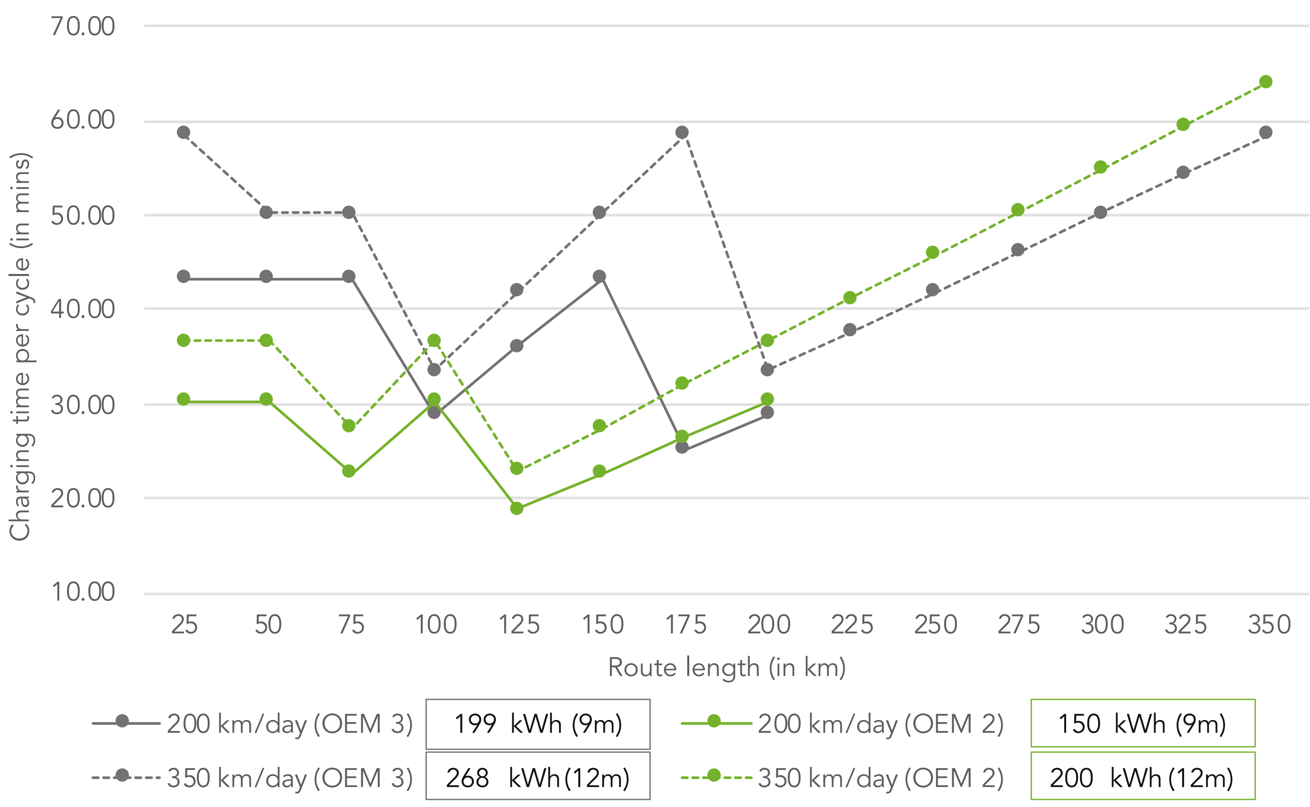
Source: Author's Analysis

However, one of the issues with the current (even fast charging) systems is that trickle charge or constant voltage phase starts around 80% - 85% per cent of SoC. This leads to a reduced window of opportunity charge or a higher layover time (if SoC > 85% is to be achieved). Thus, chargers must provide better stated efficiency to eliminate operator anxiety associated with required charging time.

We estimate the charging time needed on the varying route lengths and utilisations for a couple of OEM models (Figure 9). We deduce that current battery capacities cater to urban schedules at 75-100 km and 125-175 km long routes across the OEMs. Hence, we infer that BO is essential by route length to reduce the charging time. Thus, OEMs should offer greater battery capacity customisations to suit the route/operator specific demand across non-urban sectors.

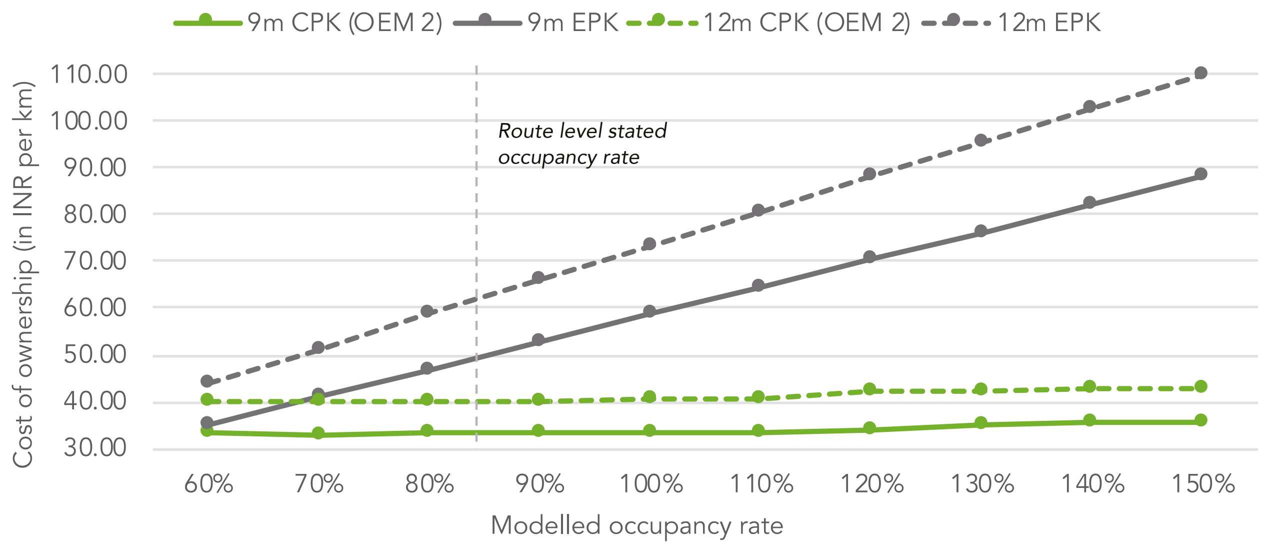
Battery optimisation is dependent on utilisation while charging time is dependent on the route lengths. Thus, bus operators must be offered a choice to modify the battery capacity.

Figure 9 Charging time required per cycle



Source: Author's Analysis

Figure 10 Occupancy rate has negligible impact on the cost of ownership of an electric bus



Source: Author's Analysis (route modelled : Thodupuzha - Pala)

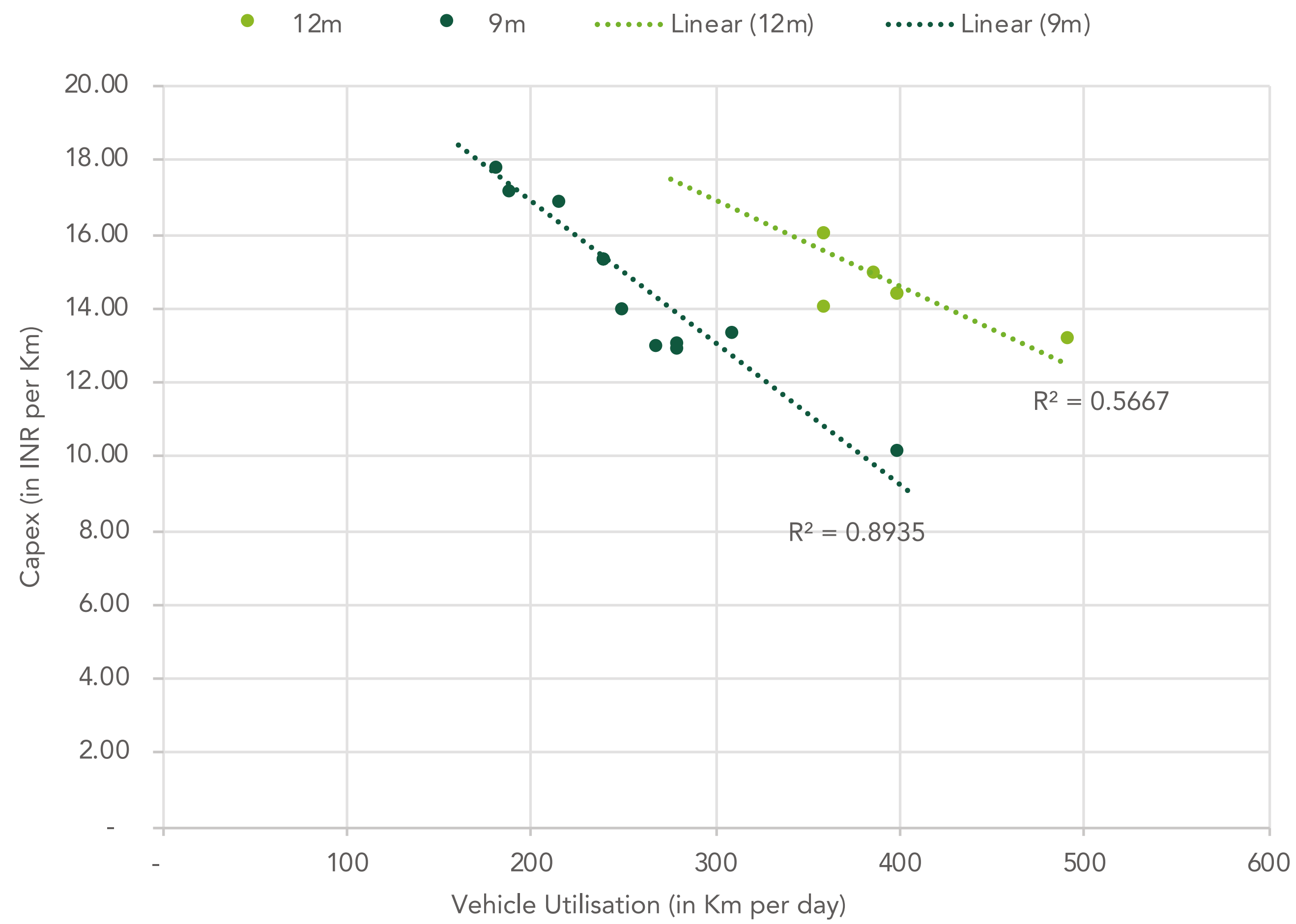
The occupancy rates of buses vary during real-world operations. The total weight (bus, passenger and impacts energy consumption (Liu et al. 2019). Thus, it is critical to assess the role of occupancy in the performance of the e-bus, subsequently on the costs. We compute the accurate energy consumption (mileage) based on the relationship between the kerb-weight of the e-bus, battery, luggage and people (Liu et al. 2019). However, due to lower energy costs, we observe that occupancy has a negligible impact on the costs per km. It has a relatively significant impact on earnings since it helps achieve greater profits (figure 10). We observe average occupancy of about 80% on non-urban routes, and it goes as high as 140% in select state geography.

2.4 VARYING E-BUS VIABILITY DUE TO ROUTES CHARACTERISTICS

Route length and vehicle utilisation impact TCOs, as observed in the previous section. The capital expenditure (Capex) of an e-bus is the up-front on-road cost of an e-bus and the total battery replacement costs. We capture variations in capex (including battery replacements) across routes to understand the role of vehicle utilisation. We find that vehicle utilisation has a robust negative relationship with capex (including battery replacement costs), as shown in the graph below (figure 11). Thus, the capital cost component of TCO of an e-bus drops with increasing per day utilisation rate of the vehicle.

For the given set of 22 AC and Non-AC routes, the route length ranges from 20 – 246 kms. Thus, we categorise the route into two categories: Mofussil routes that are < 120 km (17 routes) and long routes that are > 120 km (10 routes) (Table 3). We discuss three distinct categories of plains, hilly and AC e-bus routes separately because the operational parameters are completely different.

Figure 11 Capex has a negative relation to the utilisation of an e-bus



Source: Author's Analysis

Table 3 Categories of Routes

Category	Route length	Bus Type	Code	Count of routes
Plain	Long route	12m	12m LP	3
Plain	Mofussil route	12m	12m SP	5
Plain	Mofussil route	9m	9m SP	8
AC	Mofussil route	12m (AC)	12m S AC	1
Hilly	Long route	9m	Hilly L	4
Hilly	Mofussil route	9m	Hilly S	1

Source: Author's compilation

Routes across plains

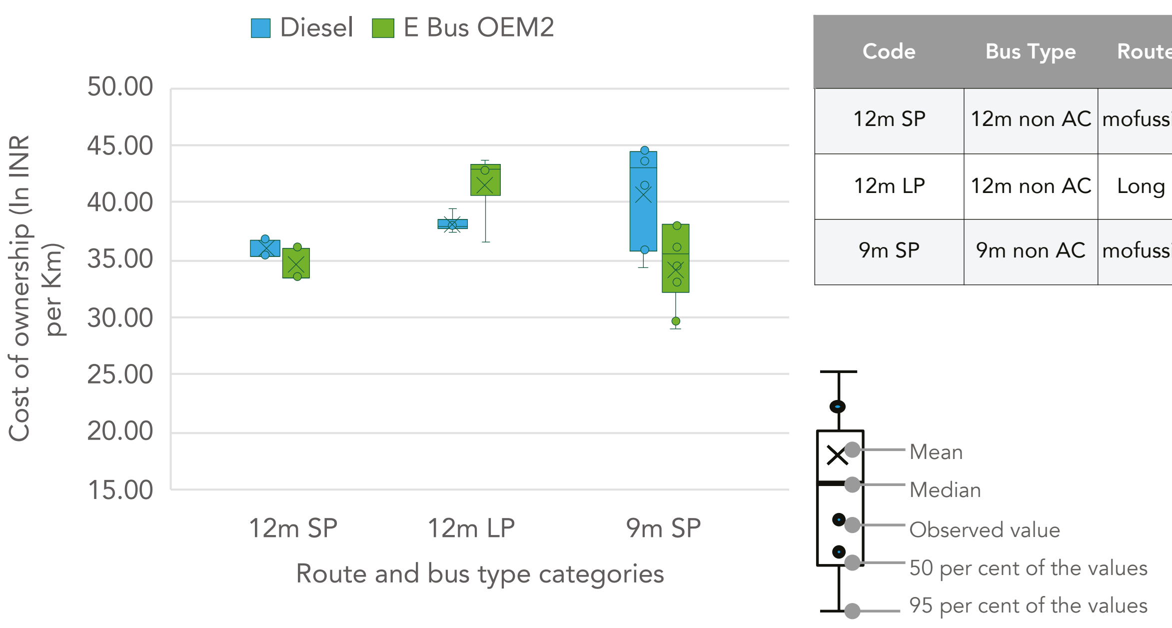
We assess non-AC bus models from OEM 2, to capture the route nuances. This helps to rule out OEM-induced variation. We estimate variability across three long and 13 short routes across plain terrain states.

For all Mofussil routes (<120km), both 12m and 9m e-bus types have lower TCO than its diesel counterparts (Figure 12). We find that for routes replaced by 9m and 12m bus models from OEM 2 (with minimum utilisation of 240 and 360 km per day respectively), the capex remains below INR 16 per km. However, for the 12m bus models from other OEMs these routes remain unviable due to larger capex per km and inefficient BO, which leads to twice the number of battery replacements during the service life (Annexure 3).

When the current 12m diesel bus models are replaced with 12m e-bus across long route lengths, longer routes with vehicle utilisation of over 400 km have cheaper e-bus TCOs. We find that CPK of 12m e-bus is expensive on three out of four long routes because of comparatively lower utilisation. We find that capex per km is highest for the route with lesser than 300 km/day utilisation. Additionally, two of these routes belong to the state with the highest staff and permit cost, coupled with lower utilisation, they have the highest opex.

However, as no route operates a 7m bus, we ran the 7m model across the existing routes. We find that the 7m buses sare unviable because the capex of 7m remains significantly higher than other bus types.

Figure 12 TCO of bigger e-bus types are cheaper than diesel across mofussil routes in plains



Code	Bus Type	Route Cat.	N
12m SP	12m non AC	mofussil route	5
12m LP	12m non AC	Long route	4
9m SP	9m non AC	mofussil route	8

Source: Author's Analysis

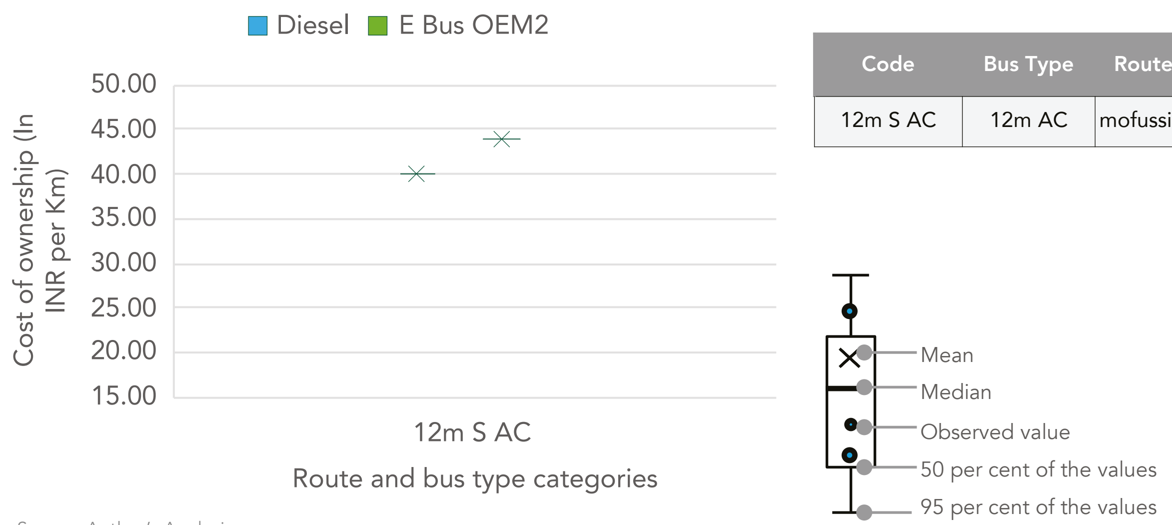
AC operations

We modelled AC e-bus from OEM 2, across one Mofussil route. The operational expenditure for the Mofussil route makes it unviable for e-bus AC adoption. Furthermore, the Mofussil route needs twice the battery replacements compared to the long routes.

Hilly routes

To further understand the performance of e-buses on hilly routes and the impact of terrain. We performed 300 km pilot operations of one 9m e-bus model in Ladakh. A spreadsheet-based analytical model incorporates the findings from these. For example, it uses data derived from the impact of terrain and occupancy levels on energy consumption. A separate report documents these findings. However, we highlight its summary in the box below.

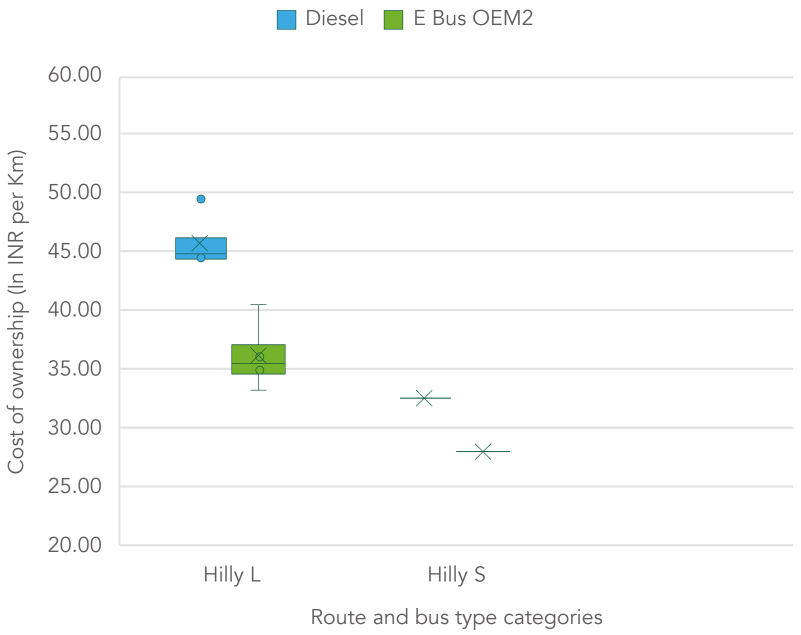
Figure 13 AC e-buses are cheaper across long routes



Code	Bus Type	Route Cat.	N
12m S AC	12m AC	mofussil route	1

Source: Author's Analysis

Figure 14 e-buses are viable across hilly routes



Code	Bus Type	Route Cat.	N
Hilly L	9 m non AC	Long route	4
Hilly S	9 m non AC	mofussil route	1

Source: Author's Analysis

Pilot Bus Operations in UT of Ladakh

E-buses regenerate electricity on downhill slopes that are steeper than -2.6% gradients. 38% additional energy is consumed per one percentage increase in gradient in an uphill drive as compared to plains, and similarly 38% reduction in a downhill drive. Additional energy consumption in an uphill drive by e-bus is compensated on the downhill drive during the return journey, thus adding no extra energy or operational costs. The observation was further validated in the test run conducted at several long routes in Ladakh.

We analysed the 9m e-bus model from the most efficient OEM, across one Mofussil and four long routes, in the UT of Ladakh. We estimate that the e-bus segment operations on hilly routes are profitable (figure 14). Between the hilly and plain terrain, the median costs of e-bus operations are 28% cheaper than those of diesel buses on long routes and 15% cheaper on the *Mofussil* routes. We find that the comparative TCOs cost saving by e-buses on hilly terrain is higher than on flat terrains. The mileage offered by internal combustion engine (ICE) vehicles on hilly terrain is lower than those provided in the plains (Wang et al. 2013). However, on average, the electric vehicle achieves almost identical mileage in hills as in plains, as the batteries' energy is regenerated and restored during descent (Box).

Savings gained from switching to e-buses is greater on hilly routes than on plains

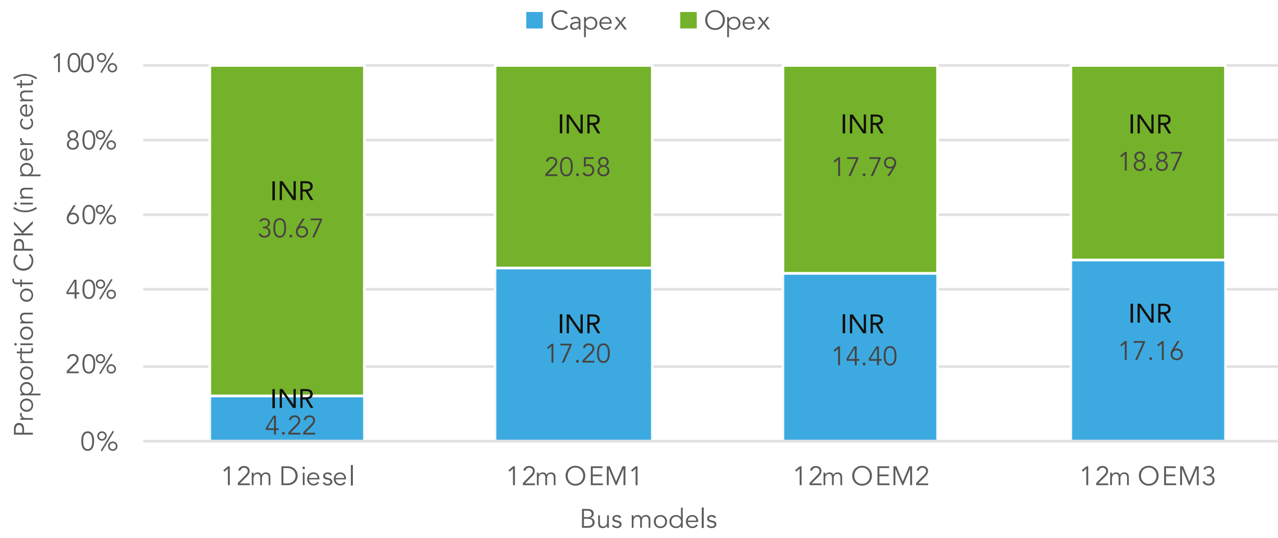
2.5 BUSINESS MODELS FOR AN E-BUS

As covered in the previous section, e-buses prove their viability across route categories. Thus, e-buses are a suitable alternative to ICE buses for non-urban operations. The high capital cost of the bus implies that the ownership model depends on commercial financing.

For diesel buses, in an ownership model, financing products are available for a tenure of 4-7 years and a relatively higher interest rate (between 9-14%). As the capex of a diesel bus is much lower than its opex (figure 15), although loan servicing reduces the profit for the operators during the loan period, it does not make it a loss-making venture.

However, we find that the financial needs of an e-bus differ significantly from its ICE counterparts. The e-bus models cost approximately three times more than diesel buses of the same size. For ICE vehicles, 1/5 of the total cost of ownership is attributed to the capital costs (capex), as reflected in figure 15. In the case of e-buses, about half of the TCO (for different bus models) can be attributed to the capital costs (including interest, maintenance, battery replacement and insurance).

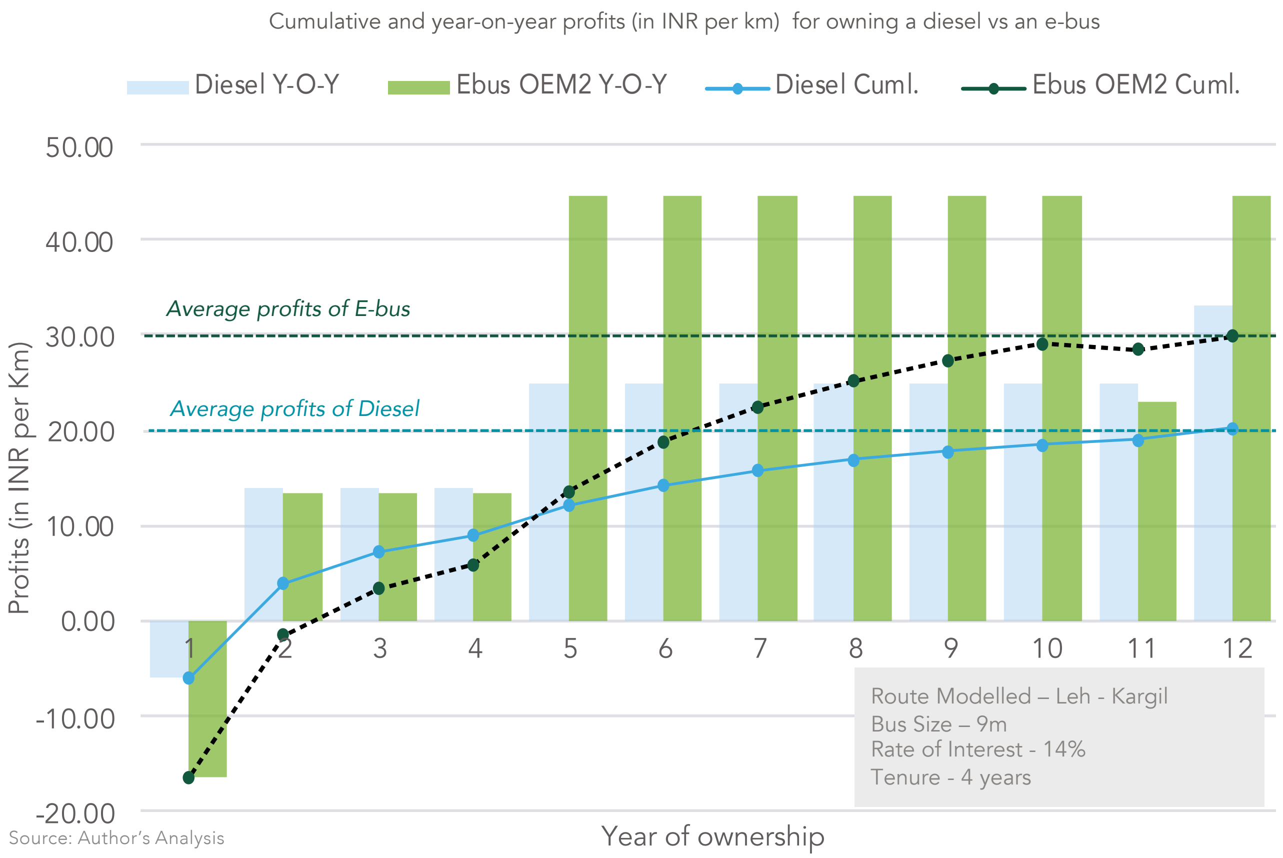
Figure 15 Capex of e-buses is four times that of diesel bus



E bus size	OEM 1	OEM 2	OEM 3
Battery Capacity (Stated in kW)			
12m	265	200	268
Fuel Efficiency (Stated in kWh/ km)			
12m	1.11	0.80	0.92

Source: Author's Analysis

Figure 16 Cost of financing makes e-buses unattractive



Source: Author's Analysis

Figure 16 highlights limitations to ownership options for electric buses under current financing conditions (interest rate of 12% for a loan tenure of 4 years). As the capital cost of an e-bus is significantly higher than a diesel bus, the operators have to sustain significant losses during the loan tenure. For the studied routes, e-bus operations incur an average of three times higher losses during the loan repayment period than diesel buses.

The financing products available in the market, both by banking and non-banking institutions, are designed for diesel buses. Furthermore, the products specific to the need of e- bus financing are missing. Thus, we infer that high upfront costs associated with e-buses dissuade operators from procuring e-buses despite their greater average profits (over service life) than diesel buses.

The FAME scheme and state EV policies provide subsidies for e-buses, but most of these are limited to public operators only. Hence, we analyse which of the various incentive mechanisms can specifically address the problem of financing e-buses.

High cost of financing makes e-bus procurement unfeasible for most private operators

Incentives to address financing barriers

We model three incentive scenarios on a typical route and with an OEM 2 e-bus model to assess the sensitivity of the TCO :

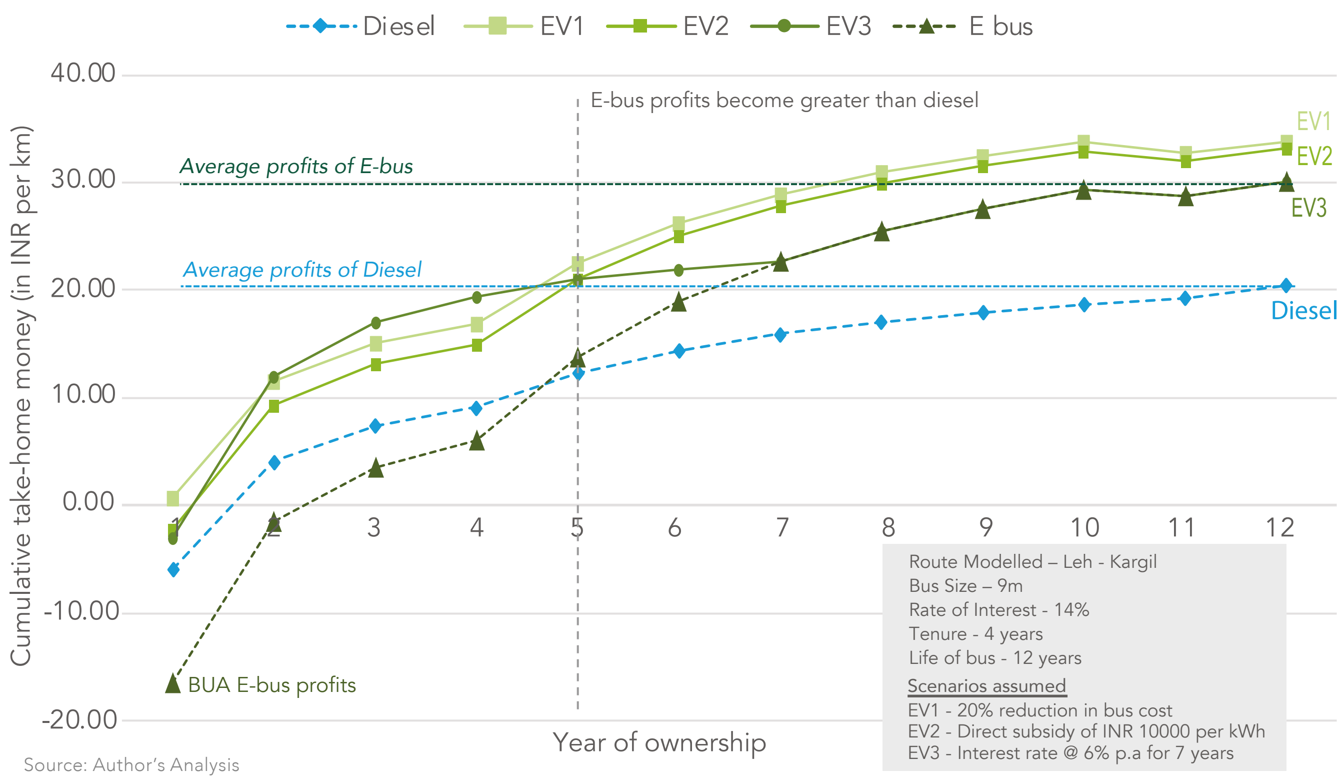
1. Incentives in bus costs
2. Incentives in battery costs
3. Reduced interest rates and longer loan tenures

Sensitivity to Incentives in bus costs
We find that an incentive of 20% subsidies in bus costs can achieve marginal profits for operators even during the loan repayments period, at an interest rate of 14% and a tenure of 4 years. (EV1 Scenario in figure 18)

Sensitivity to Incentives in battery costs
We find that e-bus operations become marginally profitable during the loan repayment period when battery prices are subsidised by INR 10,000 per kWh. (EV2 Scenario in figure 18)

Sensitivity to lower interest rates and longer loan tenures
We find that a lower loan interest rate of six percent coupled with an increased loan tenure of seven years ensures marginal profits even during the loan tenure. (EV3 Scenario in figure 18)

Figure 17 Incentives that ease the cost of finance



Source: Author's Analysis

Either of the three incentives eases most sampled routes' financing burden. The incentive to lower interest rates and increase loan tenure can be made available to the private operators through green financing, financing through bi -lateral or multi-lateral development institutions and banks. Thus, it is likely to cause the least upfront burden for the exchequer when extended to many operators.

Additionally, we checked the **sensitivity to Incentives in charging tariffs.** The model currently assumes INR. 9 per kWh as the total cost of charging, including power tariff and service charge by the CPO). We find that charging cost has a linear relationship with the total cost of ownership. However, our analysis shows that these incentives are insufficient for most routes to ease losses during the loan repayment period.

Our analysis of the **sensitivity to Incentives in battery replacement costs** notes that on routes with more than one battery replacement, reducing battery replacement cost by 20% can cushion the impact of sudden capital expenditure. However, it has no role towards easing the overall finances, as battery replacements occur beyond the loan payment tenure.

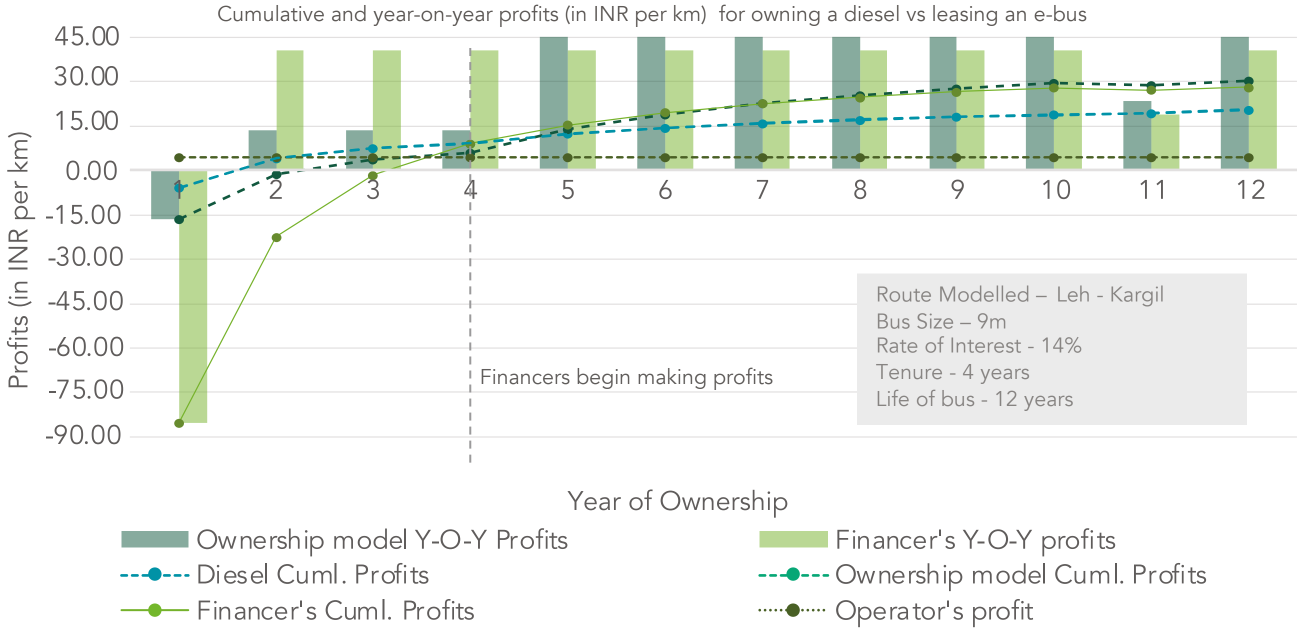
Nevertheless, as incentives only address the initial market push, they must come with a sun-set clause. To address the problem of cost of financing, we look at an alternate business model that can help outsource the high capital needs of an e-bus.

Out-sourcing capital: Lease models

The capital cost of an e-bus is the critical determinant of its viability for operators. Our analysis of the ownership model shows that the down payment of an e-bus is five times more than the diesel bus. With many private operators operating second-hand (retrofitted) diesel buses, this amount is equivalent to their current bus cost. Additionally, as seen before, e-bus operations need more financial resources to supplement the losses during the loan repayment period.

Figure 18: Lease Model eases the financial burden on private bus operators

Cumulative and year-on-year profits (in INR per km) for owning a diesel vs leasing an e-bus



Source: Author's Analysis

Acceleration in e-bus adoption requires newer business models. Thus, we envisage a lease model, where the lessor provides the bus, including the annual maintenance contract (AMC), battery replacements and insurance. While the lessee bears the staff, permit, and energy costs associated with an e-bus.

The lease model offsets the capital expenditure to financers, while utilising the operational expertise of the private operators (figure 18). Our analysis shows that e-buses require a minimum lease period of 9 years with a lease rent ranging from INR 1.5 - 2.5 lakh per month. Such a lease would ensure profits for the lessor to the tune of INR 0.5 - 2 crore over a 12-year life of the bus; while fixing the operator's earnings at INR 4.5 per km (matching current practices). The estimated average per quarter lease cost of a bus of length >10.5m (minimum 50-seater) shall be between INR 6.5-10.5 lakh, and between INR 4-7 lakh for an 8.5-10.5m length bus (minimum 40-seater) depending on vehicle model (AC, Non-AC, etc.), permit conditions (such as maximum operational kilometres, number of charging, cycles, etc.) battery pack size and route characteristics.

We conclude that currently available e-bus models are viable across non-urban routes. The bus models from one of the OEMs show business profitability across all the 22 routes. Our analysis identifies the nuances of varying route lengths and vehicle utilisation on TCOs of an e-bus. Furthermore, we have highlighted that the lease model can effectively address the challenges of an ownership model. Thus, the next chapter discusses the regulatory and legal barriers to e-bus adoption in the non-urban bus operations sector.

> Profits made due to e-bus transition can be shared to create lease models that offset the high upfront cost of e-buses to financers.

SECTION 3
ECOSYSTEM READINESS

Private operators agree that increasing fossil fuel prices make ICE bus operations unviable; hence, the future lies in transitioning to an electric bus fleet. Most operators have an ageing fleet of buses due to restricted business during the pandemic. Thus, there exists a pent-up demand which must be met soon. This can translate to accelerated electric bus adoption, given the right environment for private operators.

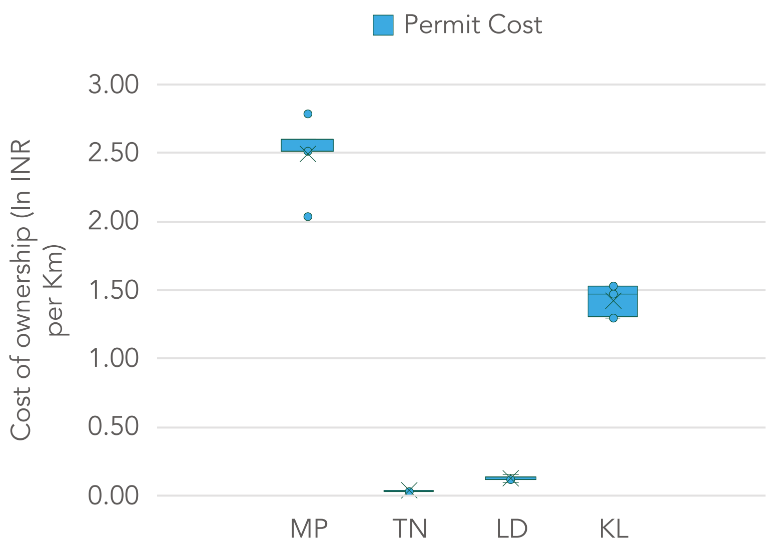
A questionnaire was designed for private operators to gather insights on gaps in ecosystem readiness to achieve the electrification of non-urban routes. We conducted a mix of one-on-one interviews, focus group discussions (FGDs), and roundtables. We observe that the operators from a state had similar perceptions and assessments of bottlenecks. This is in part due to the common permit conditions and rules. The discussion is summarised with respect to the perceived potential of e-buses by private operators on current routes. It also notes the key levers and policy actions by private operators that can help accelerate electrification in that state.

3.1 PERMIT AND STAFF COSTS VARIATIONS

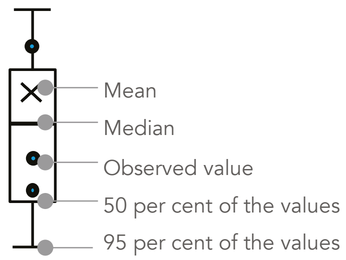
Private players operate the buses on non-urban routes under an annually renewable (for a fee) permit issued usually by the regional transport office (RTO) under the State Transport Authority (STA). Permit costs are financial instruments to regulate the market for private operators. As part of its more significant push for electric vehicles, the central government notification (MoRTH, 2018b) has exempted e-buses from needing permits across the country. However, the road map by states for implementing this policy is not defined. Currently, e-bus and its regulatory structure are evolving (especially on non-urban route), and there is a lack of clarity at the state level. Acquiring a permit is a long and tedious process; in many cases, newly purchased buses remain in-operational for months waiting for a permit. Operators fear that obtaining permits for electric buses can be equally challenging, as many of states have permit restriction around private stage carriage operations. Box below highlights the stage-carriage permit restriction across the mapped states.

- **Kerala -** Currently, permits are restricted to less than 120 km. Many permit holders are not operating buses on stage carriage routes in Kerala because of non-viable routes due to rising fuel costs. Also, the competition is stiff at many places due to rising ownership of private vehicles and falling ridership (in some cases due to competition from IPT on shorter routes). In many cases, the operators are not able to replace the old buses nearing its end of life.
- **Ladakh -** The RTO issues the permits in Ladakh in the region. The private operators apply for these permits through their association (Ladakh Big Bus Association). Operators pay a fixed annual fee to the association, which in turn arranges for the renewal of permits. Currently, the annual permit renewal is stalled because the registration of the buses on Ladakh registration system (LA numbers) is underway.
- **Madhya Pradesh (Dewas) -** Permit is provided by Dewas City Transport Services Limited (DCTSL) in the area, but the operators pay permit fees. Permit fees are high and acquiring a permit is a long and tedious process, in many cases newly purchased buses remain in operational for months waiting for a permit. Obtaining permits for electric buses can be an equally challenging process.
- **Tamil Nadu -** No new permits are being issued in Tamil Nadu, only holders of older permits can ply buses. Permit conditions stipulate the service schedule/ layover time, number of daily trips, fare conditions, occupancy, etc. The currently stipulated fare is Rs. 0.58 per/km and the maximum occupancy allowed is 100%. Additionally, permits are only issued for routes less than 120 km in length.

Figure 19 Permit relaxation has low impact e-bus TCOs



Code	State
MP	Madhya Pradesh
TN	Tamil Nadu
LD	Ladakh
KL	Kerala



Source: Author's Analysis

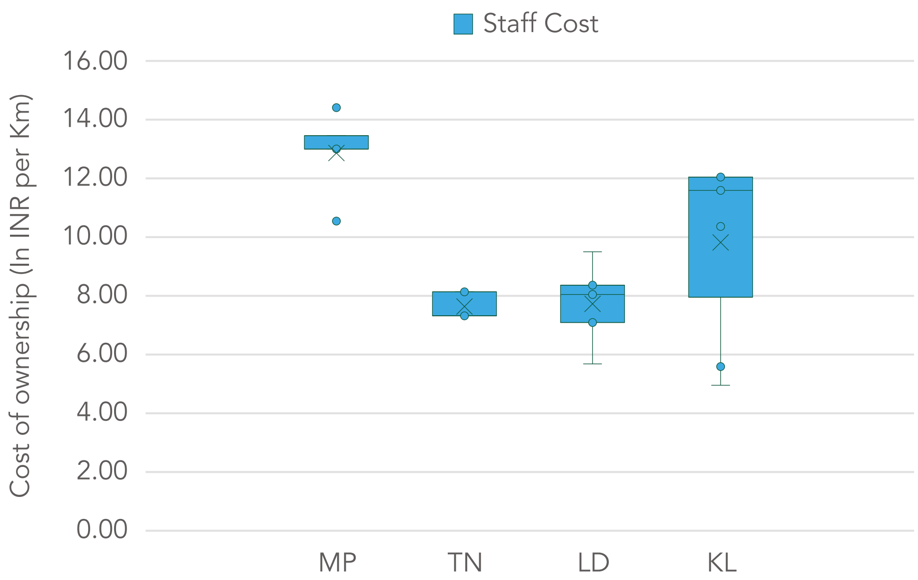
Permit costs variations across states: The annual permit fees vary between INR 4,800 to Rs. 3,48,000, and the regulated per km fare varies between INR 0.58 /km to INR 2.99 /km. As permit conditions differ greatly across states, we computed the per km costs of permits to understand its variation. We compare the permit costs across states and show the impact of it in TCOs (INR/km) (Figure 19). Inversely, we find that relaxation in permit fees can make e-buses TCOs cheaper by up to INR 2.5 per km depending on the state conditions.

Furthermore, we infer that the current permit restrictions do not favour e-bus adoptions as ownership restrictions mandate owner and operator to be the same for a bus permit. Therefore, lease models will not be permissible under current permit conditions in many states. Thus, permits for current bus operations needs to be modified for encouraging e-bus operations

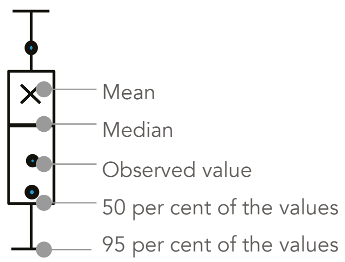
Staff costs variations across states: Another critical factor with strong impressions from the local state level governance, political maturity, cultural and socio-economic aspects is the parameter of staff costs. This includes, the competitiveness in the private bus sector, efficiency and proficiency and work ethics across states.

Staff costs for private operators remain lower than public operations, owing to higher efficiencies and access to a competitive labour market (UITP 2022). We explore staff costs impact in TCOs of bus operations, across 4 states (Figure 20). The staff costs include no of staff, deployed per bus by utilisation of bus. We find a variation of 4 - 14 INR per km between staff costs across the states. Kerala has high staff costs owing to higher salaries, despite comparatively lesser people deployed. MP has highest staff costs, owing to higher number of people (9 people) employed per bus, followed by TN (5.5 staff per bus). Currently, there is lack of experienced staff and personnel with e-bus operational experience. Operators worry that training and skilling for e-bus operations and maintenance may further escalate these staff costs.

Figure 20 Staff costs vary vastly across states



Code	State
MP	Madhya Pradesh
TN	Tamil Nadu
LD	Ladakh
KL	Kerala



Source: Author's Analysis

3.2 CHALLENGE OF CHARGING AND PARKING FOR E-BUSES

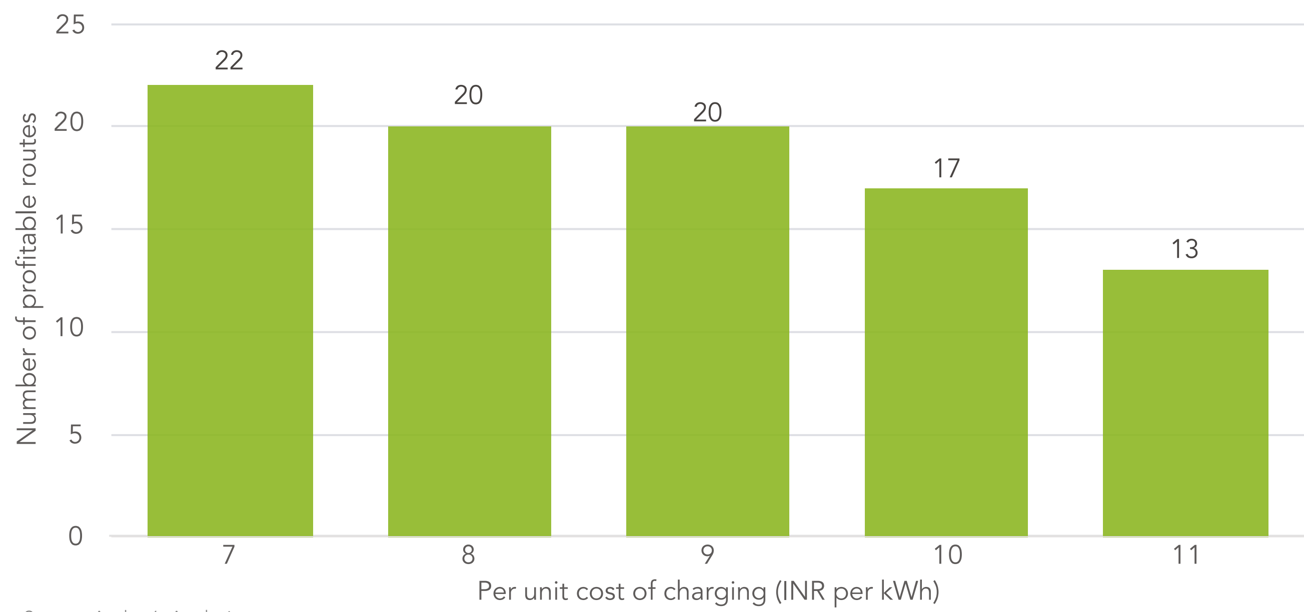
Parking lots of buses, maintenance, and cleaning/upkeep of buses have traditionally been managed by private operators at their merit. However, for e-buses, parking and charging facilities need to be combined to cut down the charging time and layover. Furthermore, charging stations require an additional land parcel, estimated at 70 - 120 sq.m. per bus (S G Architects 2017).

Most operators are small fleet owners, and it is not feasible for them to invest in even slow-charging infrastructure. Additionally, non-urban routes are longer and cannot rely only on charging at the origin. They need fast (to minimise layover time and increase operational time) opportunity charging either en-route or at the destination. These are expensive and require additional land, which means it can only be possible as a public and not a private charging facility (for electric buses). Bus operators, therefore, seek a clear roadmap from the government on the availability of fast public bus charging infrastructure and the cost of energy drawn from this infrastructure (to address any doubts that expensive public charging will negate operational cost reduction benefits). Thus, establishing charging infrastructure for e-buses requires state or private entities' investment.

To understand the sensitivity of charging costs, we model different charging rates across the 22 sampled routes to understand the sensitivity of charging costs. At charging cost of INR 9 per kWh, e-buses are cheaper than diesel counterparts on 85% of the routes . However, the count drops to 60% at a charging cost of INR 11 per kWh (figure 21). Thus, charging rates must be capped for the end user to accelerate the transition to e-buses.

Charging infrastructure, a prerequisite for running e-buses needs planned state and private investment. Gandhi et al. (2021) observes that the demand for power for charging e-buses will grow

Figure 21 Charging costs impact e-bus transition.



Source: Author's Analysis

steadily over a decade. It is estimated to grow from about 500 kWh per day in year one to about 1,350 kWh per day in 10 th year. Subsequently, the charger utilisation is projected to increase from 1.5 buses per charger to 8 buses per charger in the same duration. Thus, to attract private investment states may initially have to offer a minimum daily energy consumption guarantee per charger. Additionally, land and charger equipment incentives would further augment private investment in setting up charging stations for e-buses.

Unlike public charging stations for light EVs, bus charging infrastructure requires heavy supply of power - needs higher sanctioned capacity from the DisComs (Dhole, 2022). A special state level SPV is needed to fast-track the supply side load demand and support infrastructure. To increase private sector participation, CPOs should be provided energy cost at the rate offered by the TransCo, so that supply side support infrastructure can be assembled by them. Accessible and affordable bus charging infrastructure is critical for private bus operators. However, it is both cost and land intensive. Thus, bus charging needs to be addressed specifically in the state EV policy. A planned and shared network of bus charging infrastructure will benefit both public and private operators, accelerating the uptake of e-buses on non-urban routes.

3.3 E-BUS PRODUCT LIMITATIONS

Due to lack of experience and information (in public domain) on electric bus operations on non-urban routes, operator's concerns on effective operational range, life of the vehicle, battery life, etc., remain unaddressed. Additional concerns are around OEM's willingness to cater to electric bus demand from private operators. This stems from the lack of interest by the OEM sales teams, dealer networks etc. to offer electric buses to private operators and address any concerns/questions around it. These questions and doubts include the following:

Uncertainties associated with a nascent technology - This includes doubts on e-bus reliability in operations (especially in terms of effective range). Other doubts are on the performance in extreme temperature conditions, and the ruggedness of vehicles (sensitive electronics are used) to handle rough terrain and uneven roads/ driving surfaces.

Lack of experience with e-buses - there is limited or zero exposure of drivers and maintenance staff for e-buses. They seek more information about the buses' real-world performance over an extended period. Operators are concerned about the range limitations, product performance and pricing of the e-bus models.

Battery life and subsequent battery replacements - operators are concerned about significant capital needs for reinvestment in the bus, when the battery needs replacement. However, they are not sure about servicing, the number of such battery replacements and maintenance of the bus. There is limited confidence in OEMs delivery on warranties, with lack of trained service staff and workshop conditions in the proximity of their operational area.

Lack of customisation options – Options for changing battery size to toggle between range and costs are required. Options of sleeper seats, and luxury seats, etc. are also sought as current bus models are designed for urban specifications (more standing). Further customisation requirements include addition of custom features like AV systems, colours, designs, etc. Also reasonable range for the vehicle in single charge is considered highly important for long routes.

Availability of Type 2 and Type 3 buses - Permit conditions do not allow standing passengers on non-urban routes, and hence buses with low number of seats offer reduced capacity and thus reduced earning potential. Diesel bus OEMs are offering range and additional features with customisation options, unlike electric buses. The absence of bus models with high seating capacity and luggage storage, that are specific to the needs (Type 2 and 3 buses) for non-urban routes show a general lack of interest on the part of e-bus OEMs.

Reapproval of bus type at state level - Buses must be Automotive Research Association of India (ARAI) approved before being allowed to be sold in the open market. Some state govts impose additional state level regulations before sale is approved in their state. Removing such additional requirements will ease the development of additional bus models suited to the needs of different types of operators.

After-Sales Support - E-bus OEMs have failed to clarify after-sales support requirements for electric buses. There is little clarity about access to service and maintenance facilities, service/maintenance cycle/requirement and, costs and duration of such visit to the service centre take, etc. OEMs are currently not offering such standalone service facilities that private operators can access.

3.4 LIMITED E-BUS INCENTIVE POLICIES

It is noted in EV policy overview (CEEW-CEF 2023) that currently only a handful i.e. eight states provide additional incentives for e-buses. The type and quantum of incentive offered varies from state to state and whether it is extended to any private/ public operators (Table 4). Maharashtra offers a fiscal incentive of a maximum of INR 20 lakh per bus while Rajasthan offers a maximum incentive of 5 lakh per bus for a maximum of 500 buses. Ladakh offers a lucrative e-bus incentive of 25% of the e-bus costs (up to INR 50 lakhs /e-bus). Odisha offers additional 5% interest subvention on e-buses, registered in the state. The state of Tamil Nadu, MP and Kerala does not specifically offer any incentives on e-bus procurements.

It must also be noted that (as of Dec 2022) highest e-bus penetration, i.e. share of bus sales that are electric) for FY22 and first two quarters of FY23 is in Chandigarh (43.22%) followed by Delhi (29.39%). It is interesting to note that neither Chandigarh nor Delhi boasts of e-bus incentives in their EV policy. Thus, highlighting the political importance of the bus sector, govt support in setting up infrastructure and overall ecosystem readiness.

Experts suggest that the initial phase incentives in state EV policies for the first 400 - 500 e-buses for 3-5 years will be essential to catalyse the ecosystem. This will bolster operational data, market competition and create secondary markets for batteries and e-buses.

Table 4 Incentives on e-buses offered by various state government

State Govts	Additional e-bus incentives	Others
Odisha	10% of cost, up to INR 20 lakhs/ e-bus	5% loan interest subvention on e-buses
Meghalaya	INR 4,000/ kWh on upto 30 e-buses	
Maharashtra	10% of cost, up to INR 20 lakhs/ e-bus, on up to 1,000 e-buses	
Haryana	10% of cost on up to 200 e-buses	
Rajasthan	INR 1 lakh - INR 5 lakh as per battery capacity of e-bus, on up to 500 e-buses	15% retrofit incentive
Chattisgarh	10% of cost up to INR 1.5 lakh/ e-bus	15% retrofit incentive
Ladakh	25% of cost up to INR 50 lakh/ e-bus (50% early bird incentive)	

Source: Author's compilation

3.5 E-BUSES DEPLOYMENT PERCEPTIONS

The level of awareness of the benefits of electrification varies by state and largely amongst large and small-time operators. Private operators in Ladakh are not fully aware of e-bus technology. Despite witnessing the Jammu Kashmir State Road Transport Corporation (JKSRTC) e-buses in Ladakh, there is apprehension amongst private operators that e-buses might not be able to operate on all routes and may not achieve connectivity to remote towns. In MP, and Tamil Nadu, private operators primarily know the economic benefits and lower operations costs. They agree with its role in improving commuters' comfort, image and brand value enhancement. Assessment of perceived e-bus potential and specific levers/actions that can help overcome ecosystem gaps and accelerate electrification by operators in each geography is as following:

Table 5 Perceived e-bus potential across four geographies

State	Perceived e-bus potential	Additional ecosystem changes demanded
Kerala	High	Supporting the private operators such as Kleen Service Bus Limited (KSBL) to aggregate the demand for the electric buses and financial models to overcome the capital cost burden. Better regulatory framework to create a level playing field for the private operators.
Ladakh	High by public operator (SIDCO) and medium by private operators. Public operators see very high potential for deployment on tourist routes while private operators have concerns around their applicability on routes which connect remote areas many of which may not have reliable electricity supply.	Reduced bus cost along with reduced interest rates coupled with longer loan tenure are considered among the most effective levers in accelerating adoption of buses in Ladakh for private operators. This is followed by better access to parking/ charging infrastructure and maintenance facilities. Cheaper electricity charges and greater range are considered the least important levers.
Madhya Pradesh	Low Subsidies/grants play the most important role. The current diesel buses were bought under 40% grant as part of AMRUT.	Higher range and lower interest rate (or low capital cost) is considered as the most important lever for accelerating electrification. This is followed by options of longer loan tenure and availability of parking and charging infrastructure. Access to maintenance facilities and cheaper electricity cost is considered the least important levers.

State	Perceived e-bus potential	Additional ecosystem changes demanded
Tamil Nadu	High Private operators actively seek answers on the potential pathways towards electrification of bus operations.	Higher range and lower interest rate (or low capital cost) is considered as the most important lever for accelerating electrification. This is followed by assured accessibility to parking and charging infrastructure and maintenance facilities. Longer loan tenure and cheaper electricity charges are considered the least important levers.

Source: Author's compilation

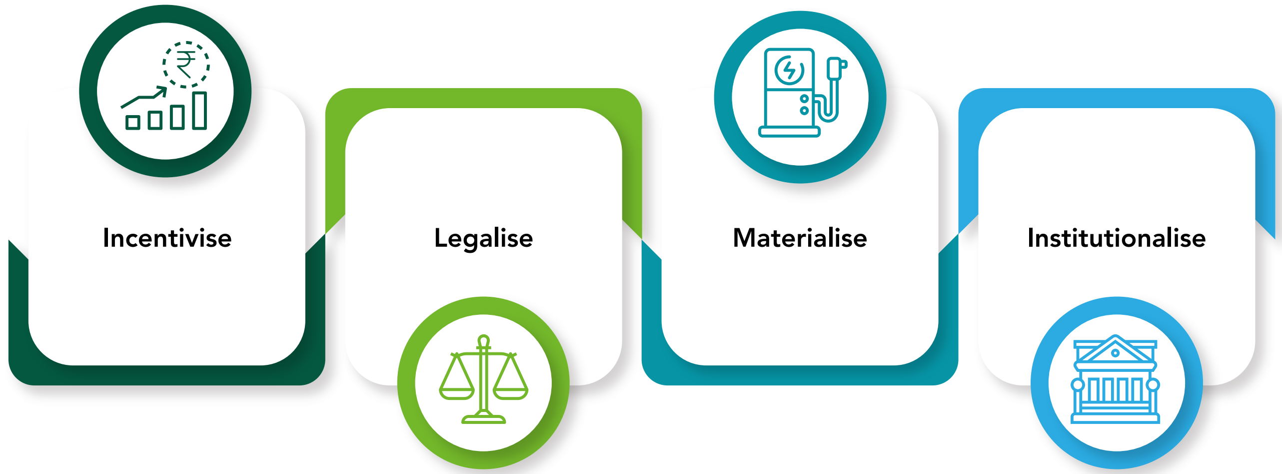
This points to a need for more pilots on non-urban routes targeting both public and private operators, and more significant marketing push by OEMs and planned communication and public outreach campaigns by the government, highlighting the performance of these vehicles in real-time world operations.

SECTION 4

RECOMMENDATIONS

Based on the stakeholder insights, discussions with industry, experts and OEMs officials, and economics analysis of e-buses, we have identified interventions to accelerate deployment. TCOs are attractive on most non-urban routes across four geographies for at least one of the OEM products. These products offer high efficiency at apt pricing. Hence, it provides the needed competitiveness in the ecosystem amongst incumbent OEMs. There is a clear need to reward high performance and high-efficiency products through adequate communications and redefining the benchmarks of quality. We make recommendations to catalyse uptake of stage carriage e-buses on non-urban routes, classified under 4 themes (figure 22).

Figure 22 Levers for e-bus transition



Incentivise to leapfrog to e-buses

E-buses have cheaper TCOs than diesel buses in non-urban operational parameters. However, under the current bus-loan conditions, we estimate that on most route (95%) operators will face higher losses than diesel buses during the loan tenure. This higher cost of financing makes e-buses non-feasible.

Many state EV policies incentivise for the first 400 - 500 buses. They will help achieve the critical level required to showcase millions of e-bus kilometres and generate a plethora of data.

It includes SOC use, charging patterns, the performance of e-buses, maintenance costs and patterns, residual and secondary market values, including unforeseen risks and opportunities. Subsequently, this will add invaluable experience amongst thousands of drivers, crew and operators, thus enriching the ecosystem and market to leapfrog. Current a few state EV policies offer direct fiscal incentives of 10-15% of bus costs or up to 20 lakh INR, for the first few hundred buses. We find that an overall reduction of about 20% bus cost can cushion the losses during loan repayment in the first four years. Alternatively, a subsidy of about INR 10,000/kWh is helpful, especially in the absence of price reduction by other measures. However, this is not sufficient unless the battery performance is also set at energy efficiency standards of 0.8 kWh/km or higher for a 9m Non-AC bus. However, subsidies must be subject to a sun-set clause. Thus, we recommend interest rate subvention as a motivator and demand generator.

1. We recommend that the union government can nudge the banks and non-banking finance corporations (NDFC) to offer a low-interest loan to operators for a maximum of seven-year tenure. The reduced interest rate shall vary between 4% to 6% based on the bus model and the consumer's credit profile. The State Government could either directly finance the reduced interest rates to the Banks and NBFCs through interest subvention schemes (like Odisha EV policy) and/or support them in accessing low-cost finance from suitable sources such as development banks.
2. Financial corporations often ask for additional collateral on loans for buses. It is feared that this will become the norm for private operators in case of loans for electric buses (due to high capital cost of buses). Operators are not keen to offer collateral other than the hypothecation of the bus. Government(s) may step in to partially hedge the financier's risk or offer a Guaranteed Emergency Credit Line (GECL) or loss-pool for both banks and Non-banking finance companies (NBFCs).

Legalise Lease model to address financial barriers

We recommend a longer-term lease model to address the high capital costs and higher financing costs in e-buses. We find that the lease model is a viable business option for the operators with the lease tenure of minimum nine years. The lease cost may vary based on the age of the bus, and the maximum service life can be 12 to 15 years. Although the lease model is viable for non-urban private-run operations, it needs adequate regulatory support to accommodate the special operational nuances.

1. State governments through the transport department could improve permit conditions specific to electric buses. E-bus permits shall be offered on both owned and leased buses, therefore permit holders can operate a self-owned or a leased e-bus on the allotted route.
2. The permit shall have an increased service operation time ceiling by 2-3 hours to compensate for time lost in opportunity charging (especially on routes where tight service schedules do not allow opportunity charging between trips). This will account for additional charging time required for e-buses.

Materialise an accessible and affordable charging ecosystem

An affordable and accessible charging infrastructure is prerequisite to e-bus operations. Increased dead kilometres add to the loss of precious service time and increase the cost of operations. Thus accessible charging infrastructure at layovers, are a must for opportunity charging. End-of-service or night time charging require adequate parking, cleaning and maintenance infrastructure for buses and crew.

We find that at 9 INR per kWh, most of the e-buses on non-urban route operations are more profitable than diesel buses. However, we propose that charging cost should be capped at 11 INR per kWh as about 40% of the selected routes become costlier than diesel bus operations at this cost.

Local Governments may adopt various interventions to manage an interim monopoly or oligopoly market of CPOs to aid accessible and affordable charging infrastructure:

1. Charging Service provider - A separate Special Purpose Vehicle (SPV) or local DisCom may be entrusted by the State Governments for charging services provision. Alternatively, it may appoint a CPO to provide these services at designated terminal points of the private operator routes, popular stops, and at other locations such as rest stops.
2. VGF for guaranteed utilisation - Up to 8 buses on non-urban routes can utilise a single fast charger, as the ecosystem matures. However, in initial years, the disaggregated supply of buses requires one charger per 1.5 - 2 buses on non-urban routes (Gandhi et al., 2021). Thus, posing risks of higher charging tariffs in initial years. Govt may intervene with VGF at pre-decided guaranteed utilisation rates, till more e-buses join the ecosystem and use chargers for planned or more utilisation.
3. Shared chargers and bus parking infrastructure - Land parcels within existing bus terminals, depots or at other government sites in the vicinity of such bus terminals/depots should be earmarked for the development of fast charging stations for private e-buses. The area requirement of such a land parcel is between 70 to 120 sq.m. per bus charging station. This land parcel could be offered for a long term, at nominal (long term) lease cost to CPOs.
4. Green charging power purchase agreements - State governments may mandate and facilitate green charging for e-buses. They may include green charging power purchase agreements with DisComs with additional investments in infrastructure for renewable power generation, where possible.
5. Promised rate of charge - The charger specifications could promise a desired rate of charge in all weather conditions. The service life of electronic equipment at each charging station is desired to be robust and long-term. CPOs require uninterrupted power supply along with steady harmonics and voltage to ensure efficient charging services.

Institutional strengthening and building a platform for private operators

Most private bus operators maintain and operate a fleet of fewer than six buses. This fragmented market needs low-cost capital and hand-holding to deal with the nascent technology transition. Thus, we recommend recognising and strengthening the unions and cooperatives of these operators to build a platform for negotiating fiscal incentives and regulatory changes.

The aggregation of such operators under an umbrella will ease the aggregation of their bus demand. Furthermore, bigger demand provides a suitable scale to establish secondary markets for buses, batteries, maintenance workshops and recycling centres. We recommend that the platform perform the following functions:

1. Such a private operators' platform will actively negotiate with the state government agencies to guarantee incentives or interest rate subvention or facilitate lease models, permit conditions and other approvals

2. Operators cite gaps in products, after-sales services and lack of data and expertise as a hindrance to buying e-bus. The platform will facilitate dialogue with OEMs to negotiate battery size, bus interiors, bus seating capacity and layouts, type-2 bus models, service centres and workshops.

3. Platform will aid the state Government with market demand to encourage secondary markets and battery recycling units set-up under the PPP model. Such infrastructure shall facilitate effective battery management and promotion of second life of battery and promise financial benefits to bus operators when they replace their batteries.

4. Platform can collaborate with the consortium of Automotive skills development council (ASDC), academic institutions and OEMs' research and development wings to exchange information. They can set up short courses and awareness drives focused on private bus operators to integrate and disseminate knowledge.

SUMMARY

We have established that TCOs of e-buses are cheaper than current diesel operations, making them a viable alternative on non-urban routes. We gather and present rich insights of operational and regulatory conditions across four geographies. These, coupled with barriers associated with the nascent technology and the high cost of capital, dissuade the uptake of e-buses.

We recommend required incentives and regulatory changes for ownership and lease-based business models. Also, we suggest creating a platform to integrate private operators' needs and facilitating a charging ecosystem for the evolving e-bus market.

Our findings provide e-bus financial planning for non-urban mofussil and long routes. It provides product insight into required bus models and battery sizing for OEMs. Financing institutions can use these findings for developing e-bus lending portfolios and leasing contracts. These findings can support governments in establishing effective incentives, regulatory mechanisms and policy provisions to help accelerate e-bus adoption amongst private operators.

However, as our analysis in the model remains on theoretical and stated inputs; it discounts factors such as temperature and driving cycles. Thus, we foresee that real-world pilots will be needed to validate the findings.

SECTION 5

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SECTION 6

ANNEXURES

Annexure 1 - E-bus model inputs from 3 OEMs:

Bus Categories	7m	9m	12m	Unit
Bus Sizes	<8.5m	8.5m to 10.5m	>10.5m	m
E-Bus cost with Battery and GST	Rs 76,99,755 to Rs 1,44,90,000	Rs 94,00,125 to Rs 1,73,25,000	Rs 1,35,03,000 to Rs 2,01,60,000	Rs
Battery Size	102 to 153	150 to 199	200 to 268	kWh
Energy consumption per km (Non-AC)	0.50 to 0.72	1, 0.60 to 0.84	0.80 to 1.11	kWh /km
Energy consumption per km (AC)	0.70 to 0.82	0.80 to 1.05	1.00 to 1.31	kWh /km
Charging cycle	2000 to 5000			
Minimum state of charge (SoC)	20	20	20	%
Maximum state of charge (SoC)	95	95	95	%
Charger efficiency	95 to 99	90 to 99	90 to 99	%
Seating capacity offered by type 1 e-bus models	21 - 24	30 - 34	33 - 39	No.
Permissible standing	10	4 - 20	15 - 24	No.
Max passengers (absolute number)	29 - 31	35 - 54	48 - 63	No.
Average curb weight of bus (without batteries)	5671 to 5820	7429 to 8900	11092 to 14000	Kg
Average energy density of battery	0.127 to 0.14	0.127 to 0.14	0.127 to 0.14	kWh/kg
Weight of battery	729 to 1205	1071 to 1567	1399 to 2110	Kg
Total weight of vehicle (with battery)	6400 to 7025	8500 to 10467	13202 to 15893	Kg
Average energy consumption	0.50 to 0.82	0.60 to 1.05	0.80 to 1.31	kWh/ km
End of life capacity of battery	80	80	80	%
Charger Capacity	200	200	200	kWh
Average battery efficiency	90	90	90	%
Battery cost per kw/h excluding GST	19050	19050	19050	Rs
Expected battery cost for replacement batteries (per kWh) excluding GST	14300	14300	14300	Rs
Servicing, maintenance, insurance, tyre change, etc. including GST (Annual cost)	300000	325000	350000	Rs

Source: Author's compilation

Annexure 2 -Route inputs from private/ public bus operators across four geographies:

Route Length	Mofussil (less than 120 km)		Long (greater than 120 km)		Unit
	Hilly	Plain	Hilly	Plain	
No. of routes	1	12	4	5	
Vehicle Utilisation	268	240-407	160-215.5	276-492	km
Frequency Proxy	4.00	3.57-12	1	1.73-3.13	
Expected EPK (in INR per km)	43	25-50	50-65	26-44	Rs

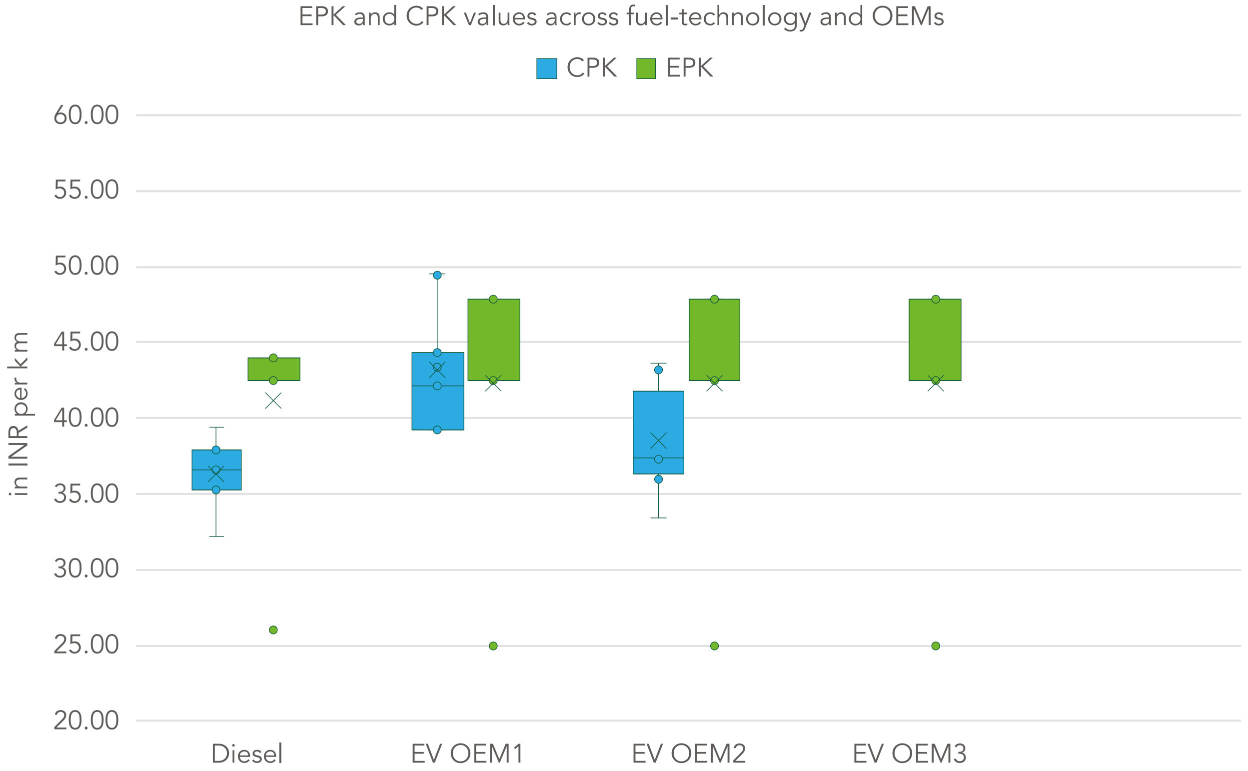
Route Length	Mofussil (less than 120 km)		Long (greater than 120 km)		Unit
	Hilly	Plain	Hilly	Plain	
Bus type	11m Non-AC (Diesel / CNG) bus	9m - 11m Non-AC and AC (Diesel / CNG) bus	11m Non-AC (Diesel / CNG) bus	11m - 12m Non-AC and AC (Diesel / CNG) bus	
Bus Cost	40,00,000	1900000-4350000	40,00,000	2200000-4000000	Rs
Fuel economy	4	4-7.5	2.75 -3	3.5-5.5	LTR/km
Fuel cost	79.77	89.76-96.51	79.77	89.76- 94.02	Rs/LTR
Service life	12	6-15	12	7-10	Years
Salary of Driver	25,000	15000-30000	25,000	15000	Rs/ Month
Salary of conductor	15,000	10000-30000	15,000	10000-12000	Rs/ Month
Maintenance staff salary	18000	18000	18,000	18000	Rs/ Month
Admin staff salary	20,000	3600-23667	20,000	15000-20000	Rs/ Month
Average number of drivers	1.1	1-2.4	1.1	1.18-1	No.
Average number of conductors	1.1	1-2.4	1.1	1.18-2	No.
Total maintenance staff per bus	0	0-0.5	0	0-0.5	No.
Total Admin staff per bus	0	0-5	0	0.4-5	No.
Servicing, maintenance, insurance, tyre change, etc. including GST	2,50,000	180000-250000	2,50,000	200000-250000	Rs
Bus terminal access cost per day	68	0-150	68	0-150	Rs

Route Length	Mofussil (less than 120 Km)		Long (greater than 120 km)		Unit
	Hilly	Plain	Hilly	Plain	
Average Seating Capacity	41	40-50	41	40-52	No.
Average Occupancy (%)	86	68-147	50-86	34-87	%
Annual Permit + Road tax	8800	4800-348000	8800	6700-348000	Rs
Current Interest Rate	14	9-12	14	12	%
Current Loan Duration	4	4- 7	4	7	year
Fleet utilisation	95	95	95	95	%
Annual total km	92929	83220-141127	55480-74725	95703-170601	km
Per pax per km earning	1.22	0.58-1.54	1.84-2.99	1.04-1.98	Rs
Total per month staff cost	44000	44320-150000	44000	46860-150000	Rs
Residual values	20	20-30	20	20	%

Source: Author's compilation

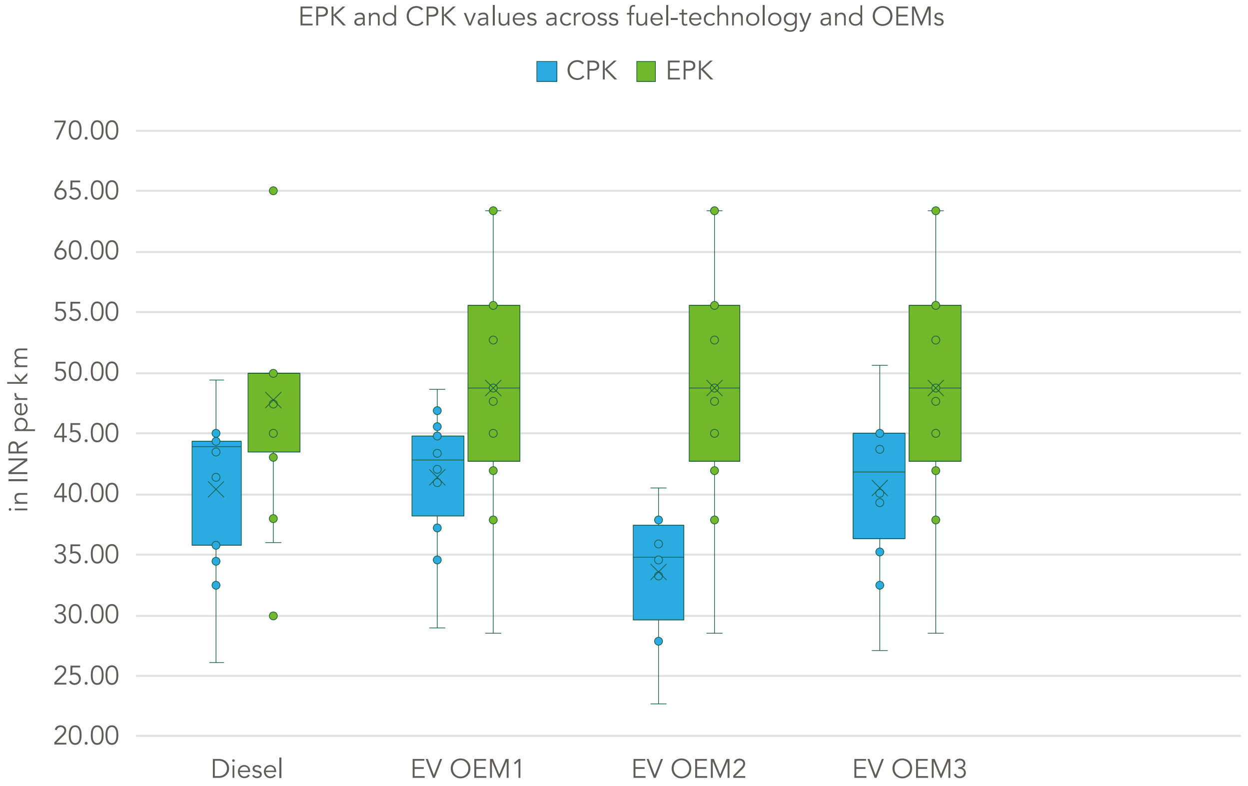
Annexure 3 – Cost and Earnings across different bus-tech, bus-sizes and E-bus OEMs:

Costs and Earnings of 12m buses



Source: Author's Analysis

Costs and Earnings of 9m buses



Source: Author's Analysis

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