ITDP INDIA

Association of State Road Transport Undertakings

GUIDANCE FOR ELECTRIC BUS ROLLOUT
IN INDIAN CITIES

As part of the project

E-mobilizing India:
Accelerating Sustainable Electric Mobility in Indian Cities

June 2022

Prepared by

The Institute for Transportation & Development Policy (ITDP) is a global non-for-profit organisation that works with cities worldwide to promote transport solutions that reduce traffic congestion, air pollution, and greenhouse emissions while improving urban liveability and economic opportunity. ITDP is represented in India by ITDP Pvt Ltd and works with governments, multilateral agencies, and civil society to make visible, on-the-ground improvements by providing technical expertise, policy solutions, research publications, and training programmes.

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Preface

In the last decade, private vehicle ownership has been on the rise, while the ridership of public transport in many Indian cities has been reducing, leading to an increased number of vehicles, and overall traffic along with their various negative externalities like congestion, air and noise pollution, anxiety, etc. These problems can be solved by encouraging people to use public transportation, which has the potential to efficiently carry a large number of people on the road.

To combat the problems of pollution and lack of buses, its fleet augmentation using electric buses has presented itself as an ideal solution as e-buses have zero tailpipe emission and 30-40% less overall emissions.[1] To accelerate the process of adaptation of electric vehicles, the Department of Heavy Industries launched Faster Adoption and Manufacturing of Electric Vehicles India (FAME India), under which a subsidy is provided for the procurement of electric buses for public use as well as to put up the supporting charging infrastructure. Benefitting from the scheme, many cities have already started electric bus operations. This report takes a look at the ebus journey so far in India.

The success of the deployment of e-buses depends on the efficient utilization of the e-buses and other assets. The report offers a guide for any State Transport Undertaking in India to plan, operate and monitor the operation of ebuses. It also talks about the various aspects of financial models deployed across the world for the procurement and financing of buses and looks at a comparative analysis of the real-world electric and conventional bus operations and financials in Pune and Pimpri-Chinchwad, and Bangalore. It also presents the total cost of ownership analysis for different kinds of buses.

[1] *Zero Emission Vehicles (ZEVs): Towards a Policy Framework. NITI Aayog. (2018)*

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1.1. Introduction

In urban India 50% of people walk and cycle to work[2], followed by public transport, two-wheelers, autos and cars. Only five per cent take cars. Public transport in Indian cities varies across geographies, but bus transportation is constant in each. While metropolitan cities such as Delhi, Mumbai, Chennai etc have multiple modes like city buses, commuter rail, and metro rail; smaller cities such as Ranchi, Gwalior, etc rely mainly on IPT rather than buses. Even in large cities like Hyderabad, Bengaluru, and Chennai, buses cater to more than 80% of public transport trips.

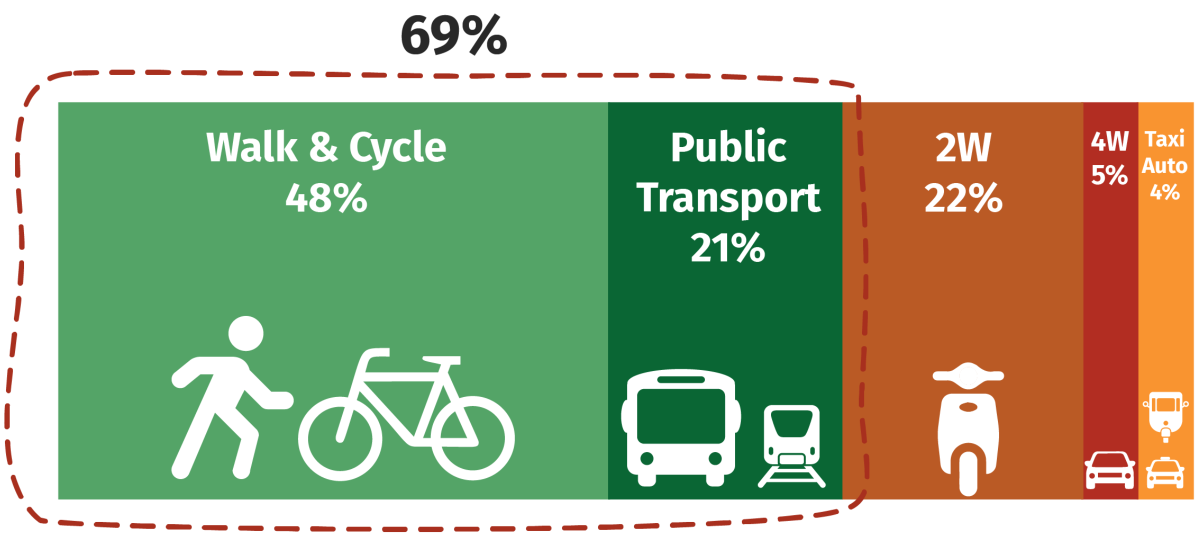

Figure 1: Mode Share in Urban India (Source: Census, 2011)

Bus services in Delhi and Bengaluru recorded close to 44 lakh and 36 lakh trips per day respectively in 2019-20[3] (before COVID-19). At first glance, the ridership stats of some cities might seem rosy, but a year-to-year comparison lays bare the problem that's brewing beneath the surface. In the past few years, declining ridership has been a cause for great concern for city bus operators.

[2] *Census of India, 2011*
[3] *Statista.com and Times of India*

Mumbai's BEST has been witnessing a steep drop in ridership—from 39 lacs a day in 2012 to 28 lacs in 2019. With multiple waves of Covid-19, there has been a further decline in bus transport ridership across all the cities.

There are nearly as many daily trips made on buses in Chennai as there are in Bengaluru. However, the fleet sizes are a sharp contrast in these two cities. Bangalore runs around 6,300 buses as compared to 3,800 by Chennai. The number of buses in other cities hasn't increased proportionately with the rise in population—resulting in overcrowding and reduced level of service.

Chennai's Metropolitan Transport Corporation (MTC) carries over 1.9 times more passengers per bus per day (1,197) than Bangalore's BMTC (623)[4] which is an indicator of overcrowding in buses. As per the Ministry of Housing and Urban Affairs (MoHUA), a city needs 40-60 buses per lakh population to serve its residents effectively[5]. Only Bangalore has close to 60 buses per lakh population in India.

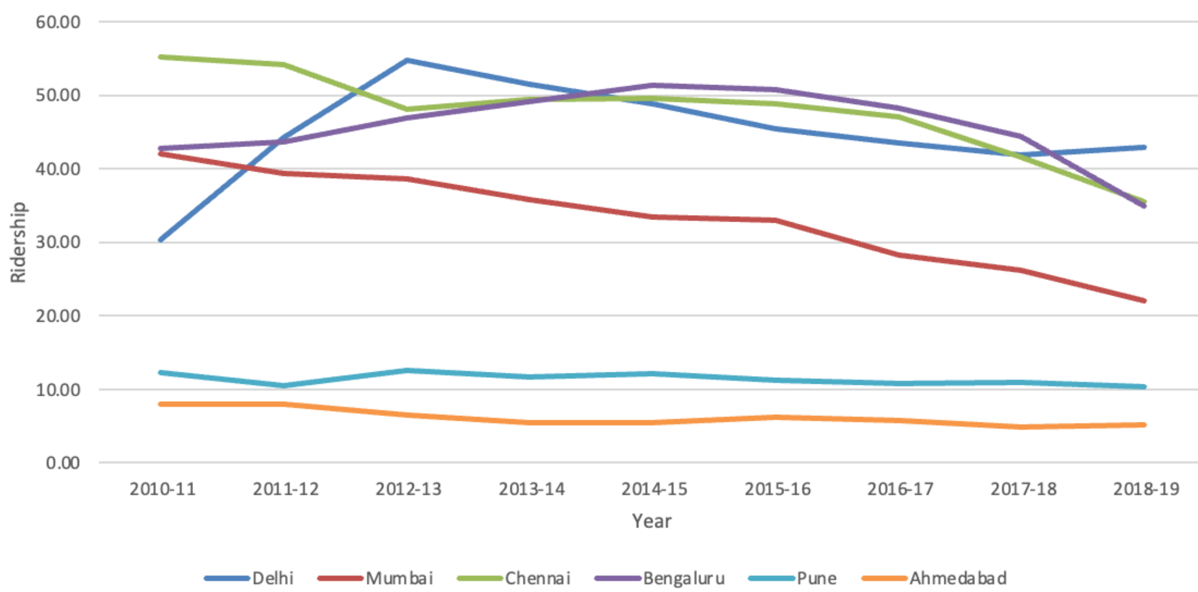

Figure 2: Declining average daily ridership (in lakhs) of urban buses in a few cities (Source: CIRT)

[4] *CIRT (2021). State Road Transport Undertakings Profile and Performance 2018-19*
[5] *http://www.utbenchmark.in*

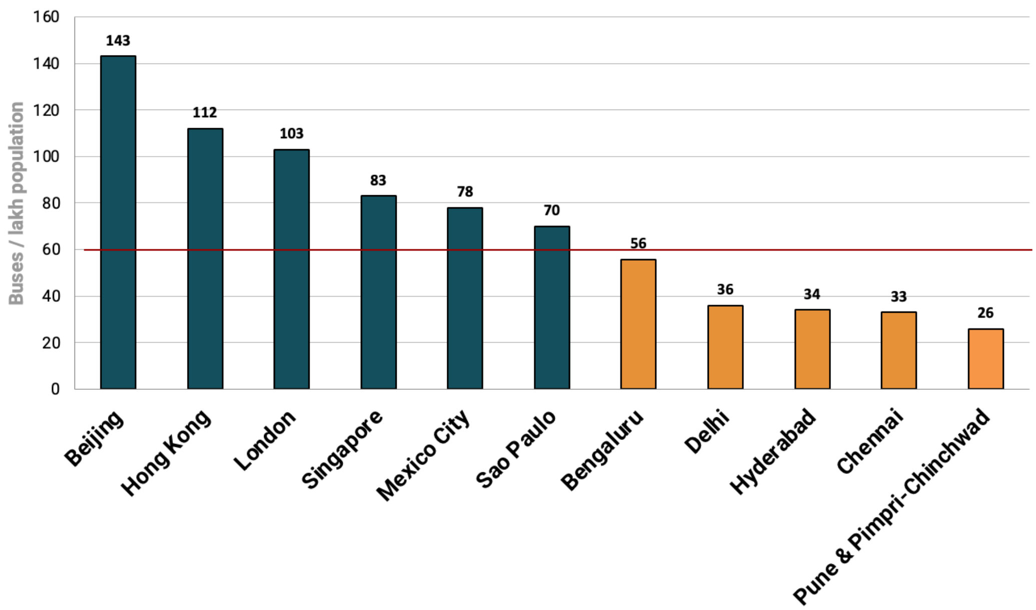

Figure 3: Buses per lakh population in 2021-22

1.2. Existing scenario and need for Electric buses

According to the service-level benchmarks[6], laid out by MoHUA for urban transport, cities should have at least 60 buses per lakh population to achieve Level of Service (LOS) 1. Most mega-cities are at LOS 3 with 20-40 buses per lakh population, resulting in a poor level of service, except for Bangalore which is at LOS 2 (40-60 buses per lakh population) and almost able to reach LOS 1. Hence, there exists an immediate need to augment the fleet in most cities.

A large number of buses in India have internal combustion engines. While efforts have been made to introduce CNG buses, many cities have suffered from a shortage in the supply of CNG. The introduction of buses with stringent emission norms has also been slow given the poor financial health of many transport undertakings.

[6] *http://www.utbenchmark.in*

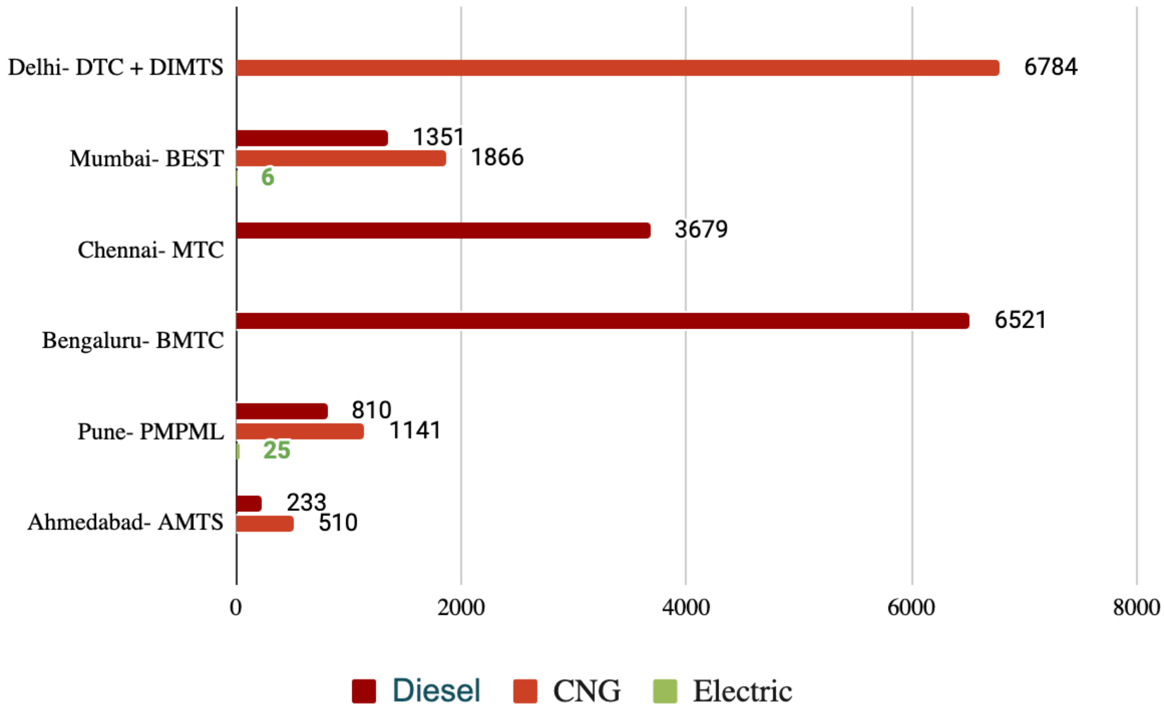

Figure 4: Buses by fuel type in 2018-19 (Source: CIRT)

In 1998, the Supreme Court of India issued a directive to replace or convert all transport vehicles (buses, three-wheelers and taxis) to CNG in Delhi by April 2001. In addition, the court specified 70 CNG refuelling stations, and financial incentives for the conversion of vehicle fleets be made available. This was a result of a Public Interest Litigation filed by environmental activists concerned with the quality of air in Delhi.

The switch to CNG showed significant results, at least initially. A study[7] by the Washington DC-based *Resources for the Future* said the conversion of buses from diesel to CNG has helped to reduce PM10, CO, and SO_2 concentrations in the city. Along with the conversion of public transport vehicles to CNG, many cities and states in India, including Delhi worked towards reducing emissions by mandating low levels of sulphur in diesel, along with stringent emission norms.

[7] *https://media.rff.org/archive/files/sharepoint/WorkImages/Download/RFF-DP-07-06.pdf*

In 2016, the Government of India issued a gazette notification[8] mandating BS VI emission norms (equivalent to Euro VI norms) from April 2020 across India.

Meanwhile, emissions from motor vehicles continue to affect the air quality. Adding to the misery, personal motor vehicle ownership is on the rise in many Indian cities. According to a study by ICCT, compared with other countries, India ranked second after China in the number of deaths attributable to transportation emissions in 2015. The study estimated 74,000 premature deaths attributable to transportation emissions in India. This represents a 28% increase in annual transportation-attributable deaths in the country compared with 2010[9].

The National Electric Mobility Mission Plan 2020 (NEMMP)[10] lists achieving National Fuel Security as one of its main objectives. India is one of the biggest importers of crude oil. The NEMMP envisioned the sale of 6-7 millions units, which can help in achieving liquid fuel savings of 2.2 – 2.5 million tonnes in 2020. This can result in a substantial lowering of vehicular emissions and a decrease in carbon dioxide emissions up to 1.5% in 2020 as compared to a status quo scenario. Greater emphasis on the electrification of public transport will certainly have a positive impact on the reduction of emissions and reliance on fossil fuels.

The Government of India deregulated the pricing of petrol in 2010 and diesel in 2014. This allowed oil marketing companies to determine the price of these products, and revise them every fortnight. Starting 2017, prices for petrol and diesel are revised on a daily basis.

As a result, the cost of diesel has increased manifold. Urban public bus service providers spent an average of ₹17.77 ($0.23) per km on fuel in 2018-19[11] with an increase of ~14% over the previous year. As fuel prices are expected to grow, transport undertakings should reconsider their spending on fossil fuels, and utilize alternate sources of energy like electricity.

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[8] *http://egazette.nic.in/WriteReadData/2016/171776.pdf*
[9] *Health Impacts of Air Pollution from Transportation Sources in Delhi, ICCT. (2019)*
[10] *https://dhi.nic.in/writereaddata/Content/NEMMP2020.pdf*
[11] *CIRT (2021). State Road Transport Undertakings Profile and Performance 2018-19*

Source - Flickr

02

Electric Buses in Pune & Pimpri-Chinchwad

Pune Mahanagar Parivahan Mahamandal Ltd. (PMPML) is the public transport service provider for the Pune Metropolitan Region that covers the jurisdictions of Pune Municipal Corporation, Pimpri Chinchwad Municipal Corporation, three cantonment areas and some areas around these regions.

As of January 2020, PMPML had a total bus fleet size of over 2,600 (including the hired fleet) out of which over 1,600 buses are BRTS compliant. The BRTS-compliant buses are high-floor buses with two doors in the center of the bus (on the right side) in addition to the conventional left side entry and exit doors. PMPML's Rainbow BRT is a hybrid BRT system where buses operate in mixed traffic lanes where dedicated corridors are not available. Thus, doors are required on both sides of the bus.

PMPML began the procurement of 150 electric buses in February 2019. It included 25 9-meter buses (Olectra K7) and 125 12-meter buses (Olectra K9), of which 119 were inducted by the end of January 2020. 15 numbers of 9m e-buses and 59 numbers of 12m e-buses were operated from Bhekrainagar depot and 10 numbers of 9m e-buses and 20 numbers of 12m e-buses were operated from Nigdi depot.

The electric buses have been procured on a Gross Cost Contract (GCC) with a 10-year service contract, extendable by two years based on performance. The conductor is provided by the PMPML while the driver and the maintenance staff are provided by the operator. PMPML pays a fixed cost per kilometre operated to the operator of ₹40.43 ($0.52) for 9-meter buses and ₹58.5 ($0.75) for 12-meter buses, with 225 as the assured kilometres per bus per day. Additionally, PMPML paid an upfront subsidy of ₹50 lakh ($64,000) per e-bus to the operator.

The total number of chargers in the two e-bus depots has been mentioned in Table 1 below. Currently, there is one charger for every 2 buses in PMPML.

Table 1: Type and number of chargers at the e-bus depots in PMPML

	Bhekrainagar Depot	Nigadi Depot	Total Chargers
80 kW (slow) chargers	41	28	69
150 kW (fast) chargers	4	2	6
Total Chargers	45	30	90

Case study: Shenzhen[12]

Shenzhen is the only city where the bus fleets have been completely electrified. The total fleet size is around 17,000 out of which about one-third are operated by Shenzhen Bus Group (SZBG).

To minimize the impact on bus routes and operations, Shenzhen adopted overnight depot charging which requires a large battery inside the buses. The daily operational kilometers per bus is around 190km. Most route lengths allow buses to operate throughout the day and buses need to be charged only at night. For a few routes, buses are charged for 30 minutes during the day and then charged overnight.

SZBG had about 1707 chargers by June 2019 - about 1 charger for every 5 buses and the target is 1 charger for every 4 buses. 50% of the chargers are 150kW DC fast chargers and 19% of them are 180kW DC fast chargers. SZBG piloted ‘network charging’ in 2016 to make more efficient use of space - one charging terminal can charge multiple buses at a time effectively reducing the rate of charging per bus. Thus, the buses are not required to move while charging overnight which saves labour costs.

[12] *Berlin, Zhang and Chen (2020). Case Study: Electric buses in Shenzhen, China*

2.1. A comparative analysis of Internal Combustion Engine (ICE) and electric buses in PMPML

Most cities are dealing with the problem of air pollution and looking for cleaner alternatives to reduce the pollution levels. Electric buses are considered a desirable option due to their soot-free operations. However, the transition to e-bus technology is expensive. E-buses cost twice as much as their diesel counterparts—making it difficult for the cities to choose between a cleaner alternative vs better services with a higher number of buses. A comparison of Internal Combustion Engine Buses (CNG and diesel) and e-buses can offer valuable insights into the viability of electric buses.

ITDP India analyzed the operational data for PMPML from February 2019 to January 2020 to assess the feasibility of e-buses as compared to ICE buses in the Indian context, whose results have been presented below.

2.1.1. Operated kilometers per bus per day (km/bus/day)

The range of the bus i.e the kms an e-bus can run in a single change, influence the km/bus/day. Hence, this indicator gives a sense of the replacement ratio of e-buses when compared with the ICE buses. The indicator can also reveal the efficiency of planning and scheduling.

In Pune & Pimpri-Chinchwad, the existing e-buses operate from two depots i.e Nigadi Depot and Bhekrainagar Depot. When the data from these two depots were compared, a significant difference was observed in the km/bus/day for e-buses. The average km/bus/day for Bhekrainagar Depot is 217 while that for Nigdi Depot is 205.5. Since the assured kilometres per bus per day promised to the operator is 225, by effective planning the e-buses could be utilized more efficiently.

Interestingly, for 9m buses, the km/bus/day at Nigadi Depot is much higher than Bhekrainagar Depot, while for 12m buses it is higher at Bhekrainagar Depot. Despite the differences, the maximum operational kilometers/bus/day for both 9m and 12m buses is 229 km in the depots. Since the 12m buses have a larger battery capacity than the 9m buses, there is further scope for improvement in the operation of 12m buses.

With the average of 207.8 km/day for ICE buses, both the 9m as well as 12m buses were able to match the performance of ICE buses, with the support of opportunity charging. Thus, the replacement ratio of ICE buses to electric buses was 1:1 with effective planning in the case of Pune and Pimpri-Chinchwad.

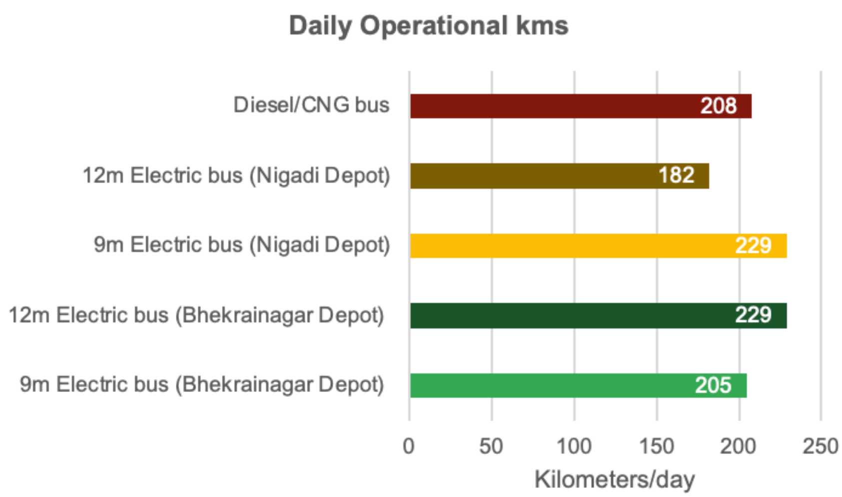
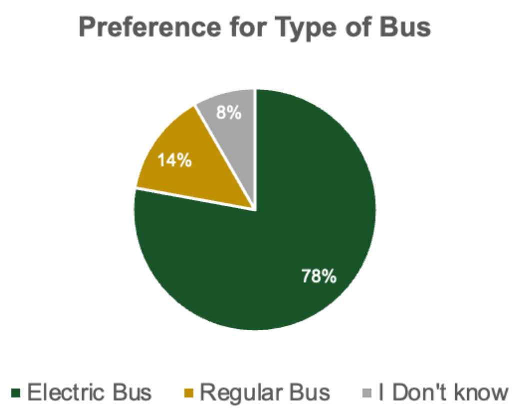


Figure 5: Operated kilometers per bus per day in Pune and Pimpri-Chinchwad

2.1.2. Passengers carried per bus per day (passengers/bus/day)

Passengers/bus/day is a factor of bus capacity as well as route popularity. E-buses in Pune & Pimpri-Chinchwad have been more popular than ICE buses. E-buses have been deployed on multiple routes alongside ICE buses. Passengers prefer e-buses over ICE buses due to better quality of service (with AC buses) at the same fare as their ICE counterparts which are non-airconditioned. Additionally, because of low vehicular engine noise, e-buses offer a quieter environment and less vibrations inside the cabin. Passengers often prefer to wait for the e-buses, leading to overcrowding on these buses. As per a survey conducted by PMPML in association with ITDP in April 2022, out of all the commuters who have already travelled in e-buses, 78% of respondents prefer to travel by e-bus.

The reasons for the preference are shown in Figure 7.



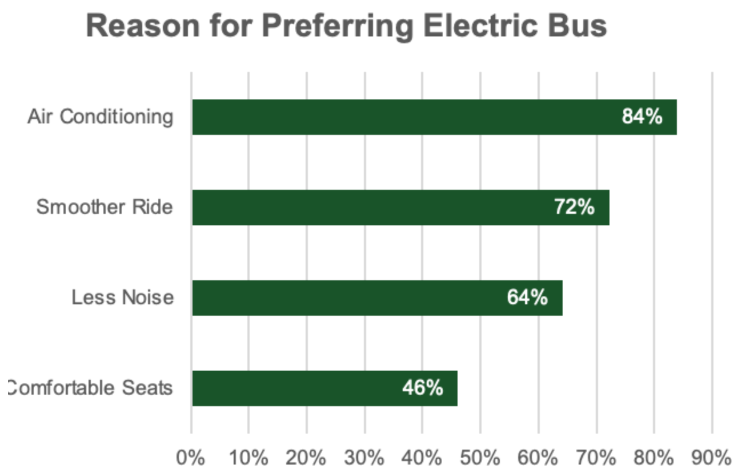


Figure 6 & 7: Preference of the type of bus and Reasons for preference for electric buses in Pune & Pimpri-Chinchwad

Passengers/bus/day for e-buses is 35% more than the ICE buses in PMPML, causing potential overloading. Overloading on e-buses can be reduced by fully electrifying a few routes and/or operating existing air-conditioned buses with other air-conditioned electric buses.

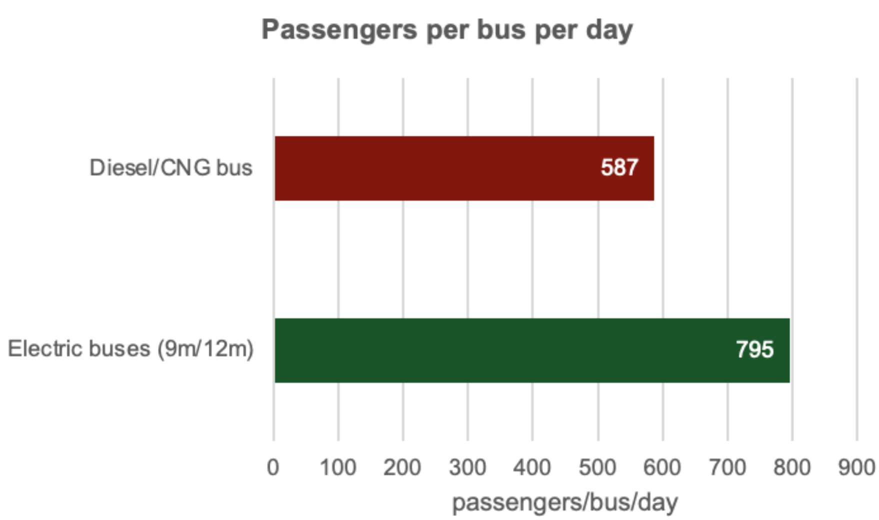


Figure 8: Passengers carried per bus per day by PMPML

2.1.3. *Energy Consumption and Emissions*

Energy consumption of the system determines how sustainable and efficient the buses are. A lot of energy is wasted in diesel and CNG engines. The energy lost is converted into other forms of energy, especially heat. Though CNG buses are slightly more energy efficient than diesel buses, e-buses are much more energy efficient than ICE buses. 12m e-buses consume 1.3 kWh per km, as compared to 2.82 kWh/km for diesel buses and 2.89 kWh/km for CNG buses. Diesel has a higher energy density as compared to CNG which means that more energy is burned per unit mass while using diesel as fuel as compared to CNG.

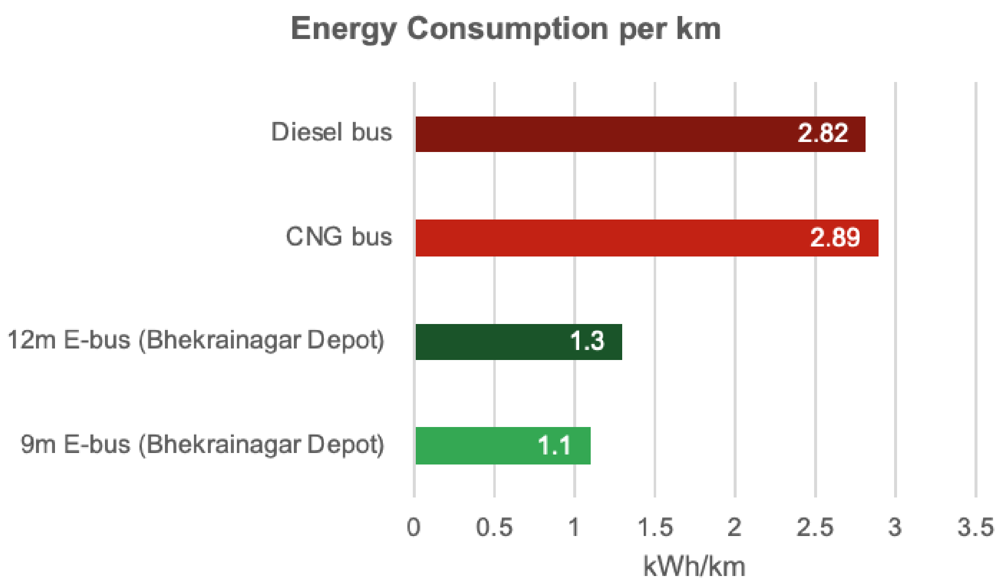


Figure 9: Energy consumption of buses in PMPML

CNG is more environmentally friendly due to lower tailpipe emissions than diesel in fast and medium-speed urban driving conditions. In low-speed urban driving conditions, Euro VI diesel buses have slightly lower emissions than CNG buses as shown the Figure 10[13] [14].

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[13] *Dallman, Du and Minjares - International Council on Clean Transportation (2017). Low-carbon technology pathways for soot-free urban bus fleets in 20 megacities*

[14] *Australia was taken as a representative for greenhouse gas emissions as the carbon intensity of Australian grid electricity is similar to that of India.*

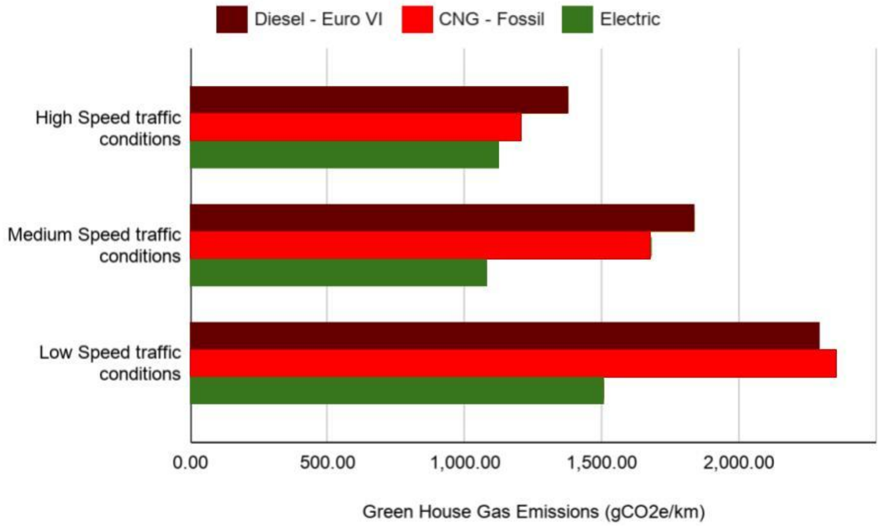

Figure 10: GreenHouse Gas Emissions in various traffic conditions for diesel, CNG and electric buses (Source: ICCT, 2017)

Case study: China[15]

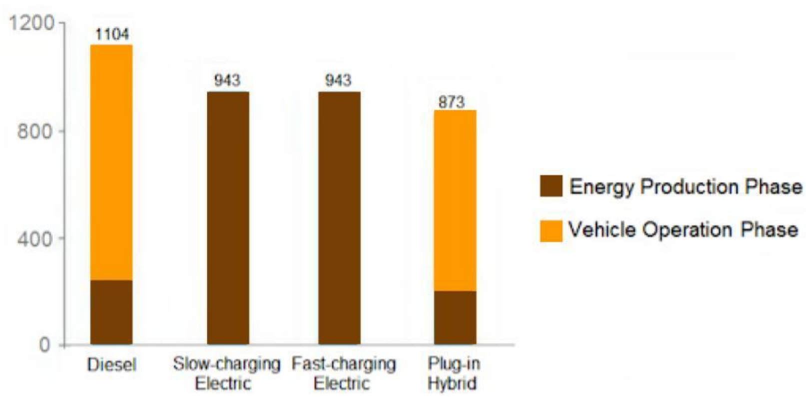

Figure 11: CO2 Emissions per km in China

The study conducted in China showed that the CO2 emissions decreased by 15-20% as compared to diesel vehicles after electrification.

[15] *Study on Demonstration Promotion and Business Model of New Energy Buses issued by the China Electric Vehicle 100 People's Congress, 2018 (https://www.itdp.org/2018/09/11/electric-buses-china/)*

2.1.4. *Mileage*

Mileage is an important metric to assess the viability of the fuel for the buses. Since the mileage is not directly comparable across fuels due to different units of measurement of fuels (kWh for electricity, litres for diesel and kilograms for CNG), the efficiency of diesel[16] and CNG[17] have been converted to a single metric of energy - kWh.

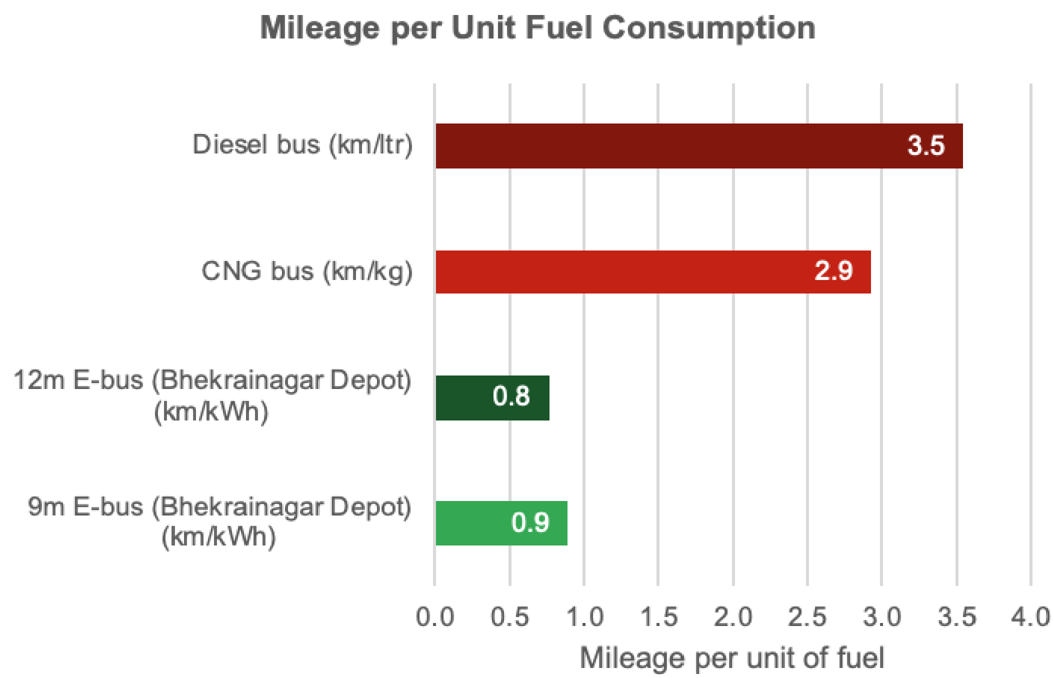

Figure 12: Mileage of buses in PMPML

The electric buses have far better mileage as compared to diesel and CNG buses. A 12m electric bus is two times more fuel efficient than a CNG and a diesel bus.

[16] *Conversion of diesel to kWh: 1 litre of diesel = 10 kWh of energy. Source: sustainability exchange. What is Energy and How Much do You Use?*

[17] *Conversion of CNG to kWh: 1 kg CNG = 1.462 x (energy content in 1 liter diesel). Source: Canadian Natural Gas Vehicle Alliance. Comparing Natural Gas To Diesel – Energy Content*

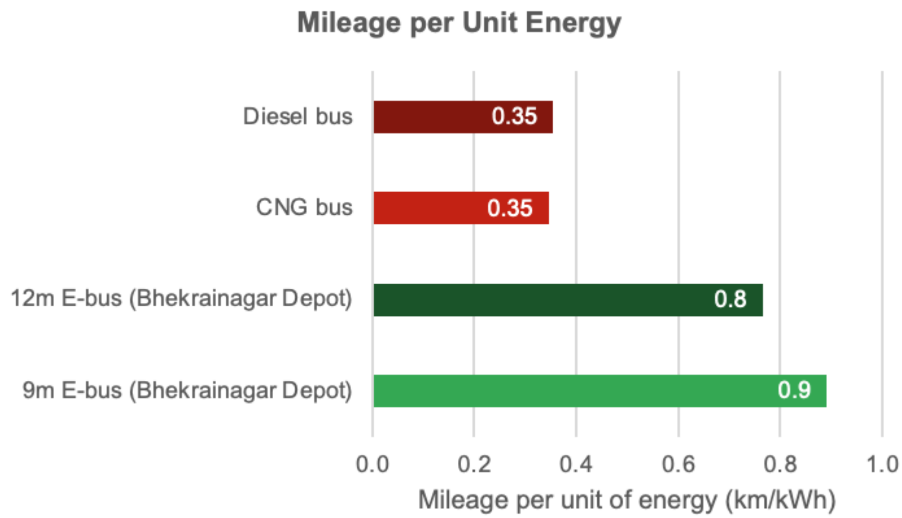

Figure 13: Mileage per unit energy of buses in PMPML

2.1.5. Average route length:

Electric buses are often criticized for their high refuelling time and limited range. Lack of charging infrastructure often leads to range anxiety that could be reflected in the route planning by the authority. However, PMPML uses a combination of overnight charging and opportunity charging during the day that enables a longer route length. The average route length for electric buses in Bhekrai Nagar Depot is 26 km which is 4.5 km higher than the average route length for ICE buses.

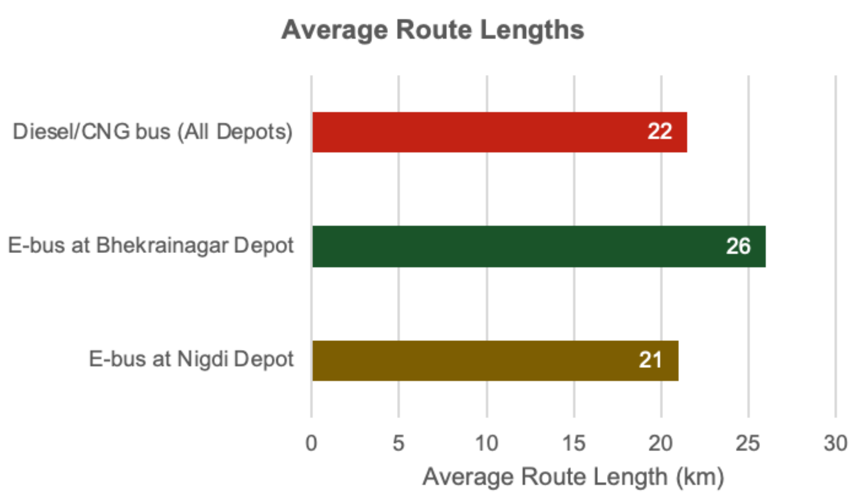

Figure 14: Average route length of buses in PMPML

2.1.6. *Fuel cost per km:*

Fuel constitutes a significant portion of the operating expenses for transit authorities, hence cheaper fuel can bring down the operating costs. In the case of PMPML, the fuel cost constituted more than 15% of the operating costs in 2018-19[18].

The fuel cost per kilometer for diesel and CNG are similar i.e ₹19.5 ($0.25) and ₹18.6 ($0.24) respectively. However, the fuel cost per kilometer for 9m and 12m e-buses is much lower - ₹5.8 ($0.07) and ₹6.6 ($0.09) respectively, which is about one-third of ICE buses.

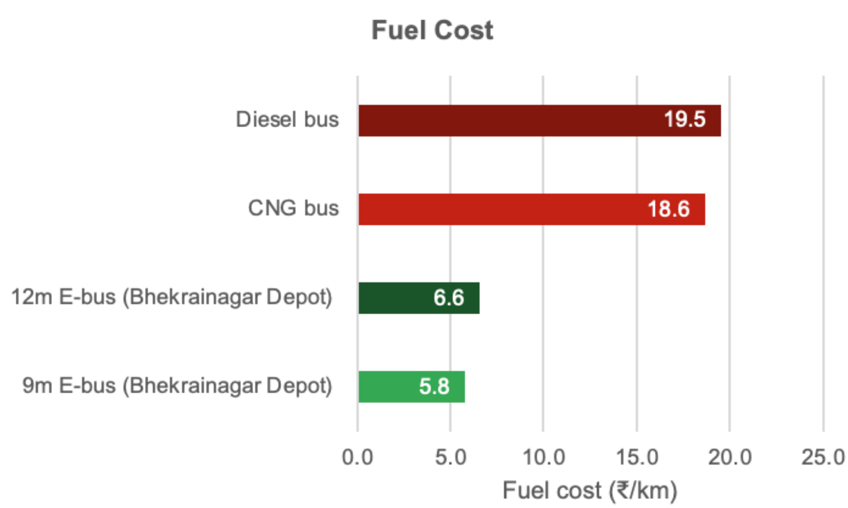

Figure 15: Fuel cost per km for buses in PMPML

2.1.7. *Cost per kilometre*

The aggregate cost of operating a bus per kilometre consists of fuel cost, personnel cost and maintenance costs.

The hired 12m non-AC CNG buses cost ₹72 ($0.92) per km to operate and are marginally cheaper than the 12m e-buses which cost ₹75.1 ($0.96)[19], despite the fact that the electric buses are air-conditioned. The 9m electric buses cost ₹56.1 ($0.72) per km.

[18] *CIRT (2021). State Road Transport Undertakings Profile and Performance 2018-19*

[19] *The cost includes the contract cost + electricity + conductor and staff costs*

This cost per km for the hired buses includes contract cost per km, fuel cost and conductor cost. The PMPML-owned non-AC ICE buses cost ₹90.6 ($1.16) per km and are the most expensive within the fleet to operate.

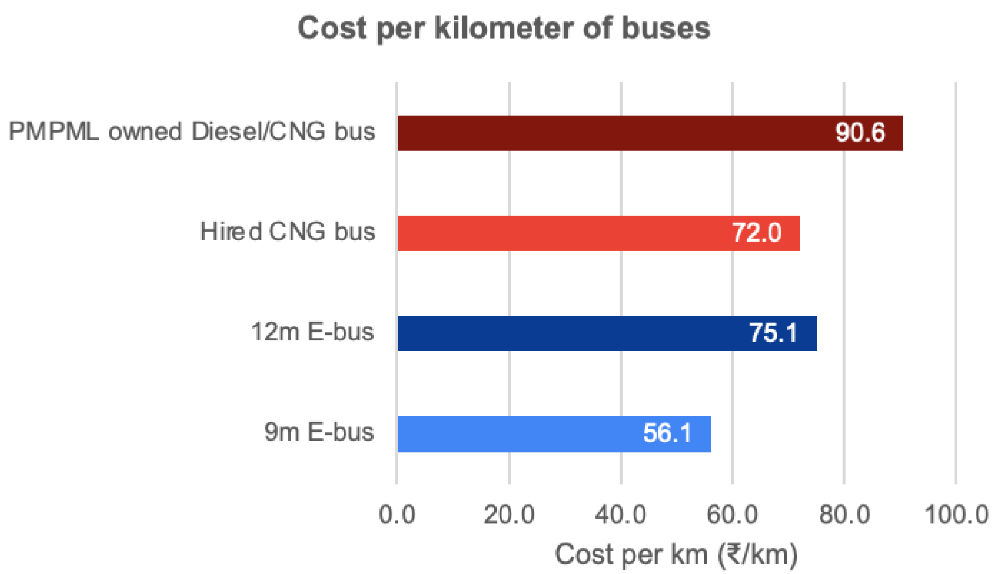

Figure 16: Cost per km (CPK) of buses in PMPML

2.1.8. Earnings per kilometer (EPK)

Earnings per kilometre is subject to the routes selected for operations. While electric buses do enjoy a higher ridership due to better comfort at the same fares, higher earnings might also be because of operations on routes that experience a higher ridership. The rollout of more electric buses can attract more ridership and help transit agencies increase their earnings while providing better services to the commuters.

The e-buses in Bhekrainagar depot are earning an average of ₹42.9 ($0.55) per km which is slightly higher than the ICE buses. The average EPK for e-buses in Nigdi depot is lower at ₹33.4 ($0.43).

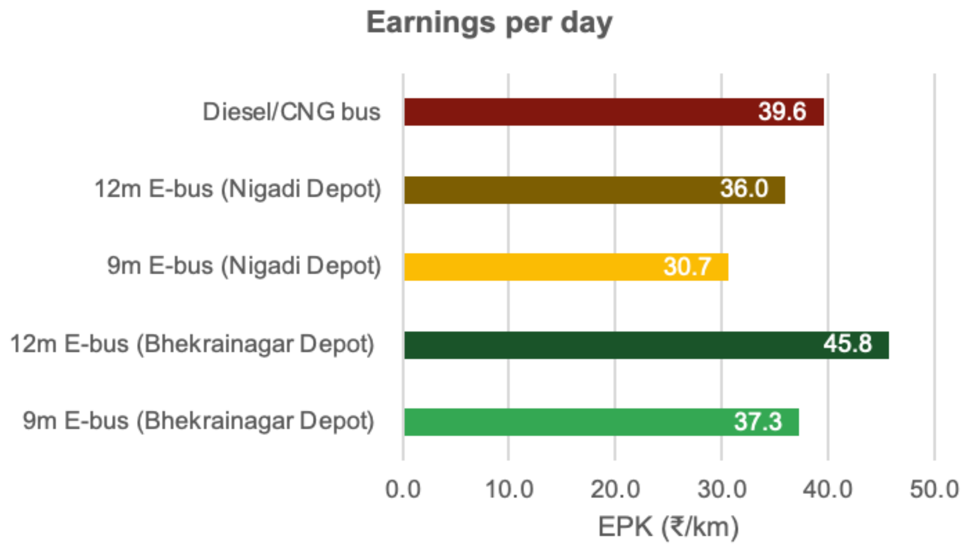

Figure 17: Earnings per km (EPK) of buses in PMPML

2.1.9. Cancelled kilometres

The cancelled kilometres is an indicator of the effectiveness of personnel management and the health of the bus fleet. While cancelled kilometres are inevitable due to some external reasons like traffic jams, accidents, etc., cancelled kilometres due to breakdowns, unavailability of buses, unavailability of staff, etc. can be avoided with better planning and maintenance of the bus fleet.

The ICE buses have a significantly higher cancellation rate than e-buses. Internal combustion engines have more moving parts and hence are more susceptible to breakdowns. Electric buses have 1.5 times lower cancellation rates than ICE buses. While the exact reasons for e-bus cancellation were not available, traffic congestion might be contributing to the cancellation.

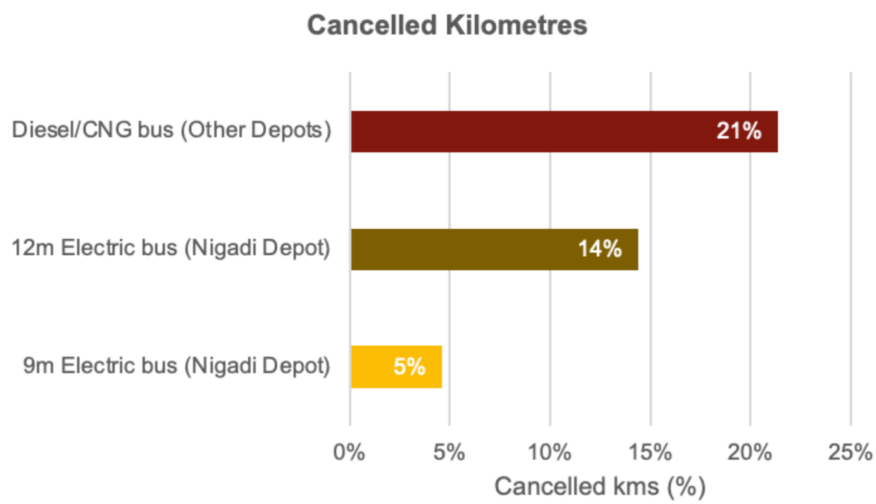

Figure 18: Cancelled kms of buses in PMPML

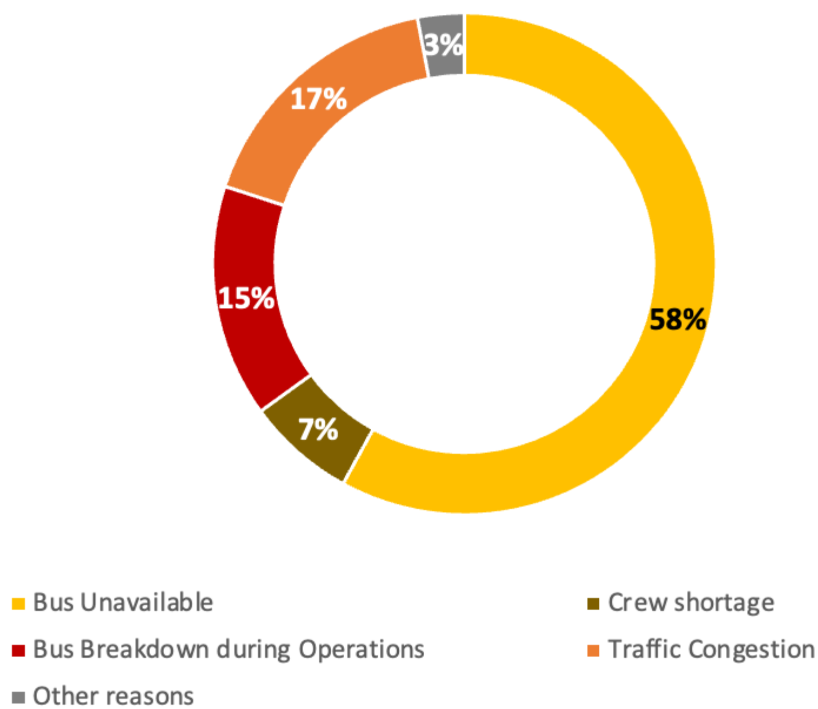

Figure 19: Causes for cancellation of scheduled kilometres for ICE buses at Hadapsar depot

2.1.10. Total Cost of Ownership (TCO)

Total Cost of Ownership is the total lifetime cost for procuring and operating a bus. The TCO was calculated assuming a 12-year operation time frame for e-buses and ten years for ICE buses based on the existing contract period in PMPML. The average daily operation was assumed to be 225 km. Maintenance costs were not added separately to hired buses.

An initial cost of 50 lakh was considered for electric buses (to account for the subsidy amount) and an initial capital cost of 48.8 lakh ($62,560) was considered for owned CNG/Diesel buses, based on the bids received by PMPML.

The current contract for hired CNG buses has an adjustment factor of 15 paise to the base price per kilometer for every 50 paise increase or decrease in the cost of CNG. For electric buses, it has been assumed that the industrial electricity tariff will increase by 6.7% annually[20]. The assumptions taken for the calculation of the TCO have been presented in Annexure 1. The total cost of ownership has been calculated using the following formula:

$$TCO = TOC \div (n * AKT)$$

Where,

TOC = Total Operating Cost over n years

n = Operational life of the bus (10 years for ICE buses and 12 years for e-buses)

AKT = Annual Kilometers Travelled

[20] *Kapardhi Bharadwaj, Karthik Ganesan, and Neeraj Kuldeep (2018) 'Retail Tariffs for Electricity Consumers in Maharashtra: A Forward Looking Assessment', May 2018.*

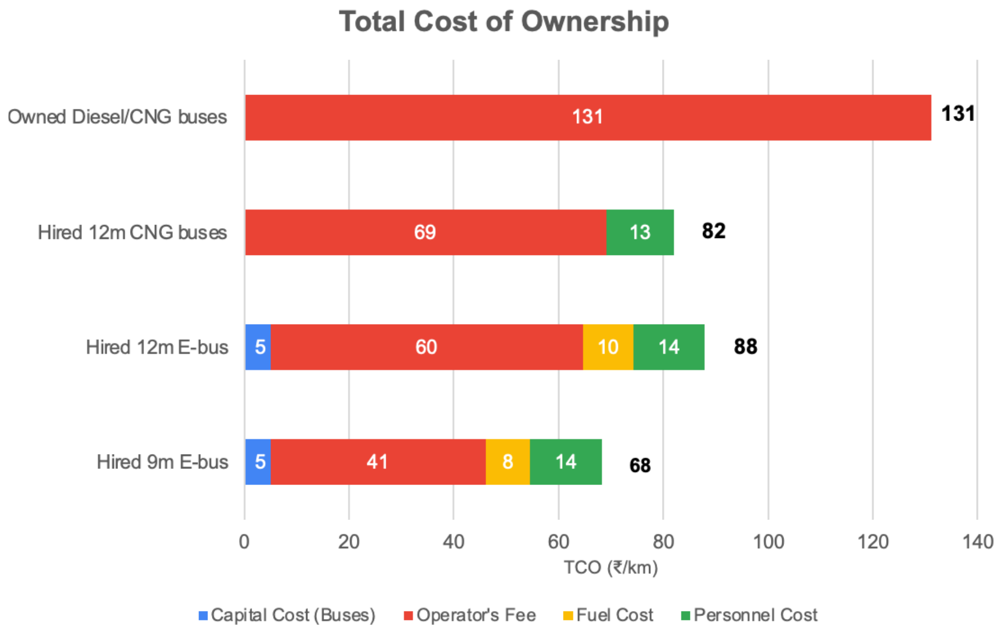

Figure 20: A comparison of the total cost of ownership of electric and ICE buses in PMPML

It should be noted that the operator's fee for owned buses is assumed to be the total cost of operations for PMPML. The TCO for 12m AC e-buses is marginally less than the hired non-AC CNG buses and much lower than the non-AC owned diesel/CNG buses. Lower fuel cost, lower cancellation rate, better earnings per kilometre and better energy efficiency are some of the greatest advantages of e-buses over ICE buses. Additionally, e-buses also offer a much better quality of services due to lower noise and vibrations and other features like air-conditioning at a relatively lower cost.

Case study:

A comparison of the total cost of ownership of electric buses and internal combustion engine buses by LBNL and WRI

Lawrence Berkeley National Laboratory[21] (LBNL) has estimated the TCO for 12m AC electric buses in India at ₹37/km ($0.47) (without subsidy) which is significantly lower than 12m diesel buses estimated at ₹59/km.

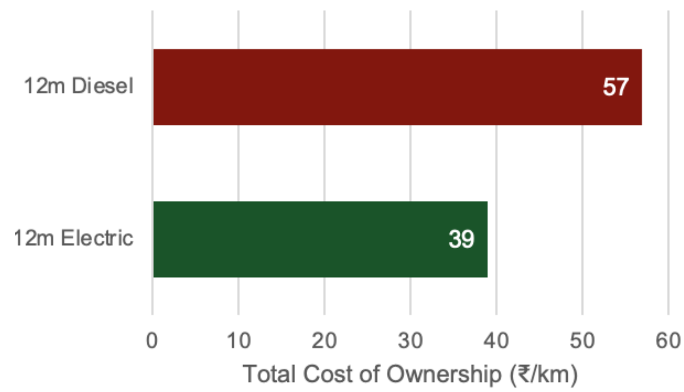

Figure 21: A comparison of the total cost of ownership of electric buses and diesel buses (Source: Lawrence Berkeley National Laboratory, 2018)

A study by the World Resources Institute[22] has shown that the TCO of an electric bus decreases with an increase in its daily operational kilometers (Figure 21). The TCO almost matches that of high-cost AC diesel buses when they are operated for over 200 km/day.

[21] *International Energy Studies Group, Lawrence Berkeley National Laboratory (August 2018). Techno-economic analysis of bus electrification in India*

[22] *Kumar and Chakrabarty (2020). Total Cost of Ownership Analysis of the Impact of Vehicle Usage on the Economic Viability of Electric Vehicles in India*

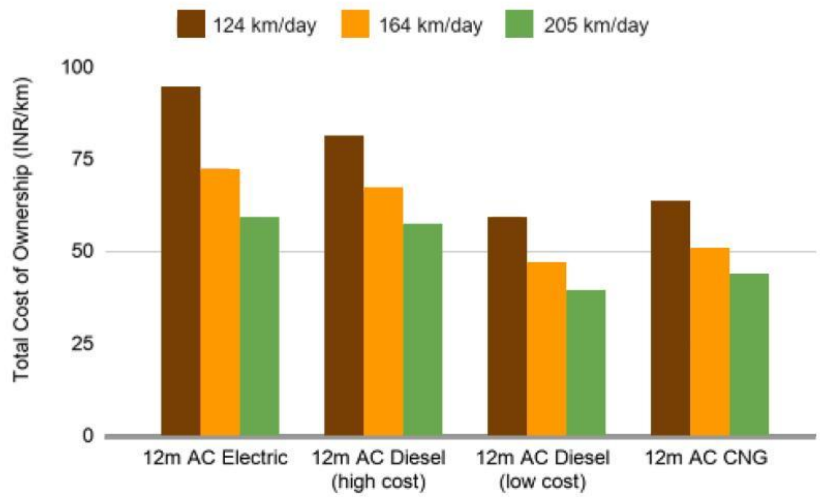

Figure 22:A comparison of the total cost of ownership of electric buses and internal combustion engine buses (Source: World Resources Institute, 2020)

2.2. Conclusion

Electric buses are more efficient to operate compared to ICE buses. PMPML has been able to provide better quality service with e-buses as compared to non-AC CNG buses with a marginally higher total cost of ownership. The diesel/CNG buses owned by PMPML are the most expensive to operate. The total cost of ownership reduces with an increase in daily utilisation.

Fuel is also much cheaper for electric buses. The electric buses are more reliable and thus have a lower trip cancellation rate.

The environmental footprint drastically reduces with electric buses as they require lower energy per kilometer to operate. They also provide a much better service to the commuters with soot-free operations and lower noise and vibrations inside the buses.

Considering the benefits, it is advisable for the urban bus operators to transition to electric buses, not just to reduce the emissions (that also depends on how clean the electric grid is), but also to improve the financial and operational performance with better quality of services.

Source - Business Insider India

03

Comparison of e-Bus Operation in Hyderabad and Pune & Pimpri-Chinchwad

A comparative analysis of electric buses between two cities can explain the effect of the differences in the planning and utilisation of the buses on their performance.

Table 2: Comparison of E-bus operation in Hyderabad and Pune & Pimpri-Chinchwad

Indicator	Hyderabad E-bus (12m)	PMPML E-bus (12m)
Kilometer/bus/day	351	225
Energy Efficiency of bus (kWh/km)	0.98	1.3
CPK (excluding personnel cost and fuel cost)	33.12	58.5
Fuel cost per km (₹ ($))	8 (0.10)	6.6 (0.09)
Average route length (km)	43.75	26

Hyderabad's daily bus operations of its electric buses are 126 km (56%) more than that in Pune & Pimpri-Chinchwad. As the total cost of electric buses reduces with higher utilisation, Hyderabad may have been able to negotiate a better price than Pune & Pimpri-Chinchwad. The energy consumption is much lower in Hyderabad than in Pune & Pimpri-Chinchwad. The fuel cost is marginally lesser in Pune & Pimpri-Chinchwad but the total cost per kilometer is much lower in Hyderabad. Higher energy efficiency may be linked to longer routes, but there are many other factors that might be affecting the efficiency, such as driver training, traffic conditions, loading on the bus, etc.

Source - Times of India

04

Comparative Analysis of Internal Combustion Engine (ICE) & e-Buses in Bengaluru

4.1. Introduction

Bengaluru Metropolitan Transport Corporation (BMTC)- the public bus operator in Bangalore, was one of the early movers in planning to induct e-buses into its fleet. The first trial operations were held as early as 2014. However, it was not successful in securing a contract to operate the e-buses in its initial few attempts owing to the higher cost per kilometer (CPKM) of e-buses.

At times, the CPKM of the existing fleet of ICE buses is computed on the basis of historical costs, without considering the full cost of capital and future increases in fuel, maintenance, and replacement costs, which are often compared with the CPKM of new e-buses based on the cost of owning and operating them for the perspective 10-12 years. This results in an unfair comparison. The following analysis will show a like-to-like comparison of the total cost of operation of the ICE and e-buses and how a more suitably structured contract could result in more favourable quotes for e-buses.

BMTC operates three types of services - Luxury 12m AC Bus Service (for airport transfers and corporate staff), Standard 12m Non-AC service and Midi 9m Non-AC service. The facts and assumptions used in this analysis pertain to BMTC's operations and may not be comparable to other operators. The analysis assumes BMTC's ownership of the buses and is not compatible with costs attained with gross cost contracting which involves private capital, subsidies, private sector efficiencies, the effect of contractual conditions and risks as well as counterparty credentials.

4.2. Methodology

Diesel and electric buses have varying capital and operating cost components and therefore in order to compare the commercial competitiveness of each, it is necessary to use a method of aggregating the costs over the economic life of the buses adjusting for the time of incurring the expenses.

Capex costs are one-time costs which include procurement cost of the buses along with necessary infrastructures such as depot space, charging etc, excluding any subsidy, while Opex costs are recurring costs which include operational and maintenance (O&M) costs, fuel costs, labour costs and other miscellaneous costs.

To determine TCO per km for different bus segments, the following equation is typically used[23].

$$\frac{\mathbf{TCO}}{km} = \frac{\left(PC - \frac{RV}{(1+r)^N}\right) X\,\mathrm{CRF} + \frac{1}{N}\sum_{n=1}^{N} \frac{\mathrm{AOC}}{(1+r)^n}}{\mathrm{AKT}}$$

Where,

PC = purchase cost of the vehicle;

RV = residual value of the vehicle at the end of the period of analysis;

CRF = capital recovery factor;

AOC = annual operating cost of the vehicle;

AKT = annual kilometers travelled;

r = discount factor;

N = lifetime of the vehicle (in years)

The capital recovery factor (CRF) is calculated using the following equation:

$$\mathrm{CRF} = \frac{r(1+r)^N}{(1+r)^N - 1}$$

For TCO calculation, input data was collected from sources like research articles, reports, vehicle manufacturers' websites, and so forth.

The data relating to BMTC's operations were obtained from their administrative reports which are quite detailed. Annexure 2 provides the summary of the purchase cost, annual operating cost (AOC), and details of mileage and battery capacity of EVs etc.

[23] *Wu, G., A. Inderbitzin, and C. Bening. Total Cost of Ownership of Electric Vehicles Compared to Conventional Vehicles: A Probabilistic Analysis and Projection across Market Segments. Energy Policy, Vol. 80, 2015, pp. 196–214*

4.3. TCO Analysis

Based on the above methodology and assumptions, the TCO comparisons under various bus segments are as follows for the daily operation of 180 km/day/bus.

4.3.1. *Different Bus Types*

As seen from Figure 22, in the case of the 9m non-AC and 12m AC buses, the TCO for e-bus is less than that of the diesel bus whereas the TCO for the standard non-AC e-bus is higher than the comparable diesel bus. This is mainly on account of the relatively higher acquisition cost difference (net of subsidy) between the diesel and electric standard non-AC buses as compared to other variants.

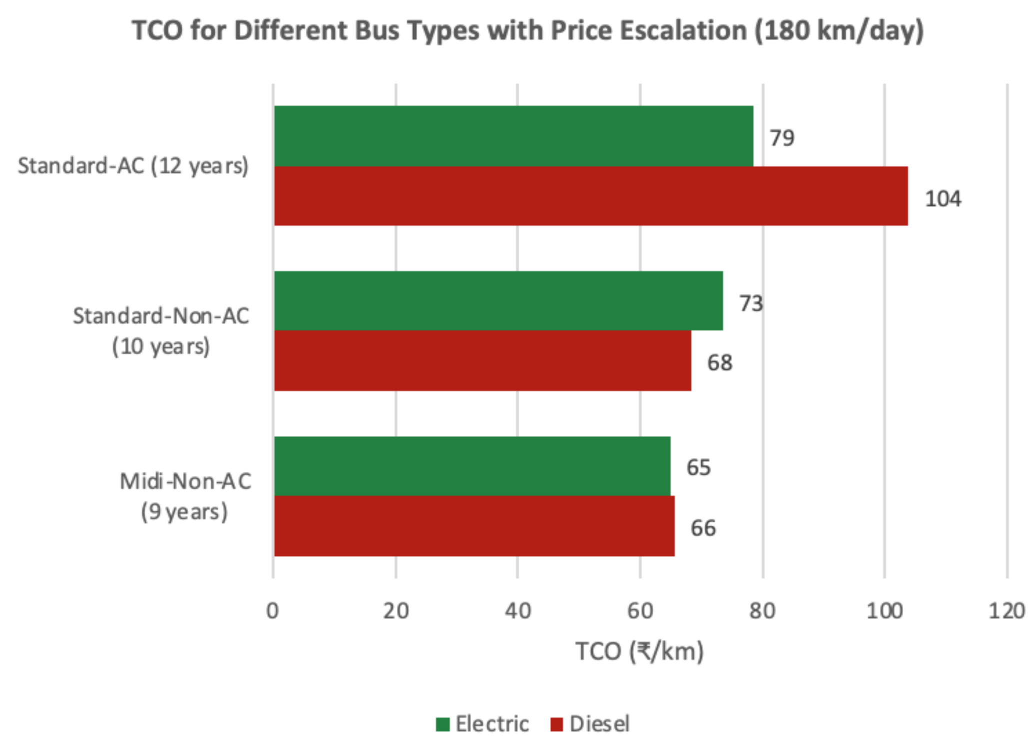

Figure 23: Total Cost of Ownership for different types of buses

The total cost of ownership includes the capital cost, manpower cost, fuel cost, maintenance cost, overheads, motor vehicle tax and cost associated with battery/overhauling.

Figure 24 shows the breakup of various cost components for each type of bus.

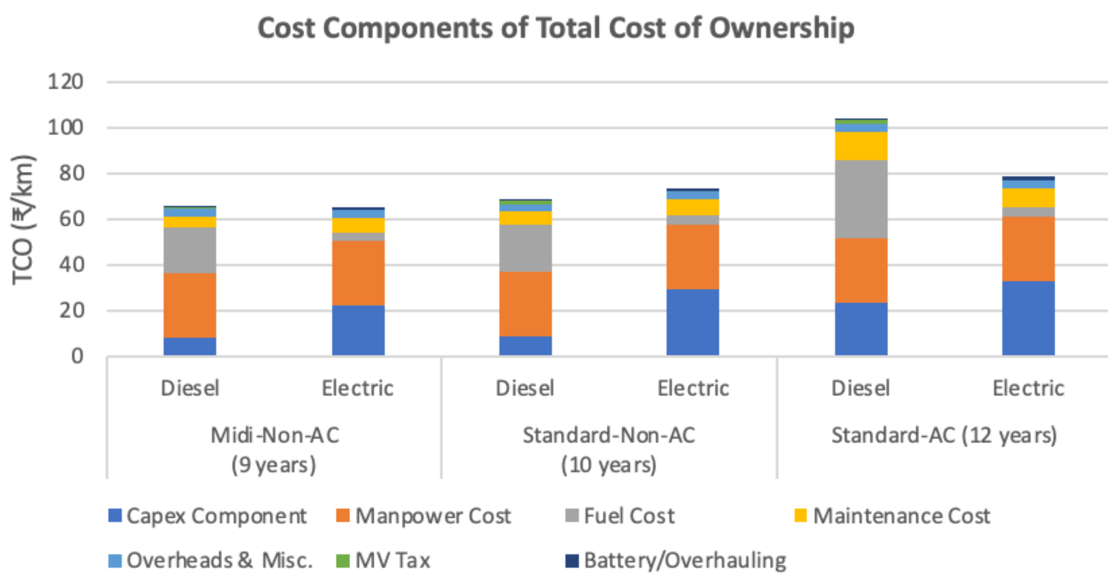

Figure 24: TCO for different categories of diesel and electric buses

To check the variation of TCO with other parameters, sensitivity analysis is carried out for different procurement years, daily utilization and level of subsidy.

4.3.2. *Different implementation years*

To evaluate the trends in TCO for diesel and electric buses, the following assumptions are made:

a. The e-bus prices are likely to decrease in coming years due to economies of scale, research and development as well as the reduction in inputs especially, the battery prices. Between 2010 and 2016, electric cars showed a learning rate[24] of 23% in Germany[25].

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[24] *Learning rate indicates reduction in costs for every doubling of cumulative production.*
[25] *Martin Weiss, Andreas Zerfass, Eckard Helmers;"Fully electric and plug-in hybrid cars - An analysis of learning rates, user costs, and costs for mitigating CO2 and air pollutant emissions"; Journal of Cleaner Production, Volume 212,2019,Pages 1478-1489,ISSN 0959-6526*

The historic learning rate for EV lithium-ion battery prices from 2010–2018 was around 18%[26]. Assuming a doubling of E-bus production every 4 years, an annual reduction in E bus costs, say at 5% per annum, is assumed.

b. The diesel bus prices will increase due to an increase in material prices, say at 2% per annum. Diesel prices will increase at 5%[27] per annum as compared to electricity prices which are much more stable and will increase at 1.5% per annum based on past trends of the wholesale price index of electricity published by the Government of India.

Based on the above-assumed scenario, the variation of the TCO for different bus segments is shown in Figure 25 to Figure 27 for the bus to be acquired in the years 2022 to 2030.

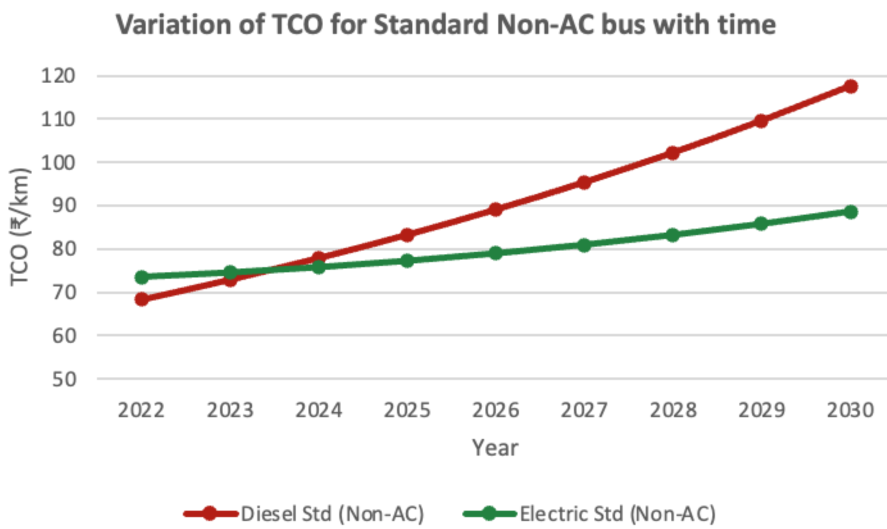

Figure 25: Movement in TCO of 12m Non-AC Diesel and E-Bus with time

[26] *Hanhee Kim, Niklas Hartmann, Maxime Zeller, Renato Luise and Tamer Soylu; "Comparative TCO Analysis of Battery Electric and Hydrogen Fuel Cell Buses for Public Transport System in Small to Midsize Cities"; Energies 2021, 14, 4384.*

[27] *The World Bank expected that petroleum prices are expected to increase by 21% by 2030 as compared to 2019 whereas the US Energy Information Administration projects an increase of 75% over the same period in dollar terms (Knoema). Rupee depreciation will also impact diesel prices. The rupee has depreciated by about 4% p.a. from Rs. 50.58/USD January 16, 2012, to Rs. 73.92/USD on January 10, 2022.*

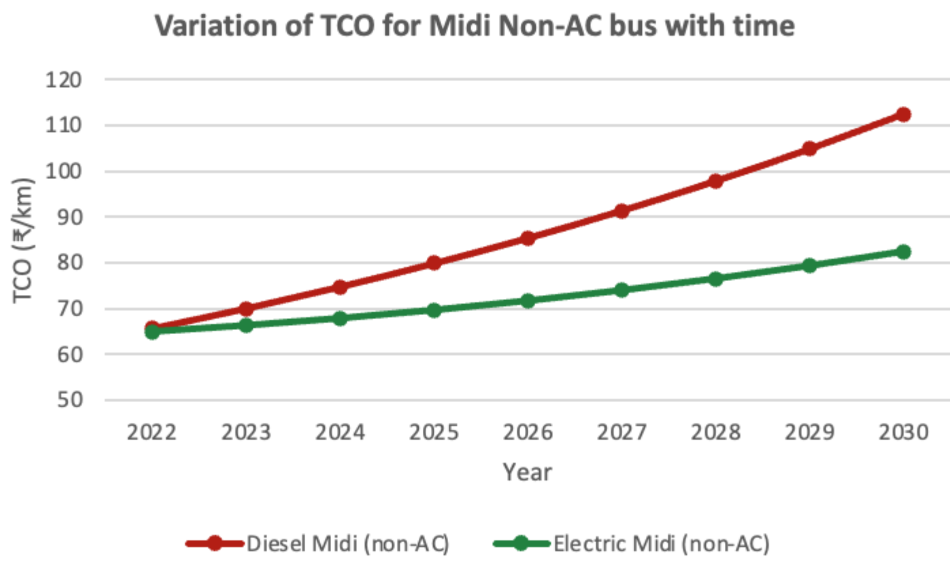

Figure 26: Movement in TCO of 9m Non-AC Diesel and E-Bus with time

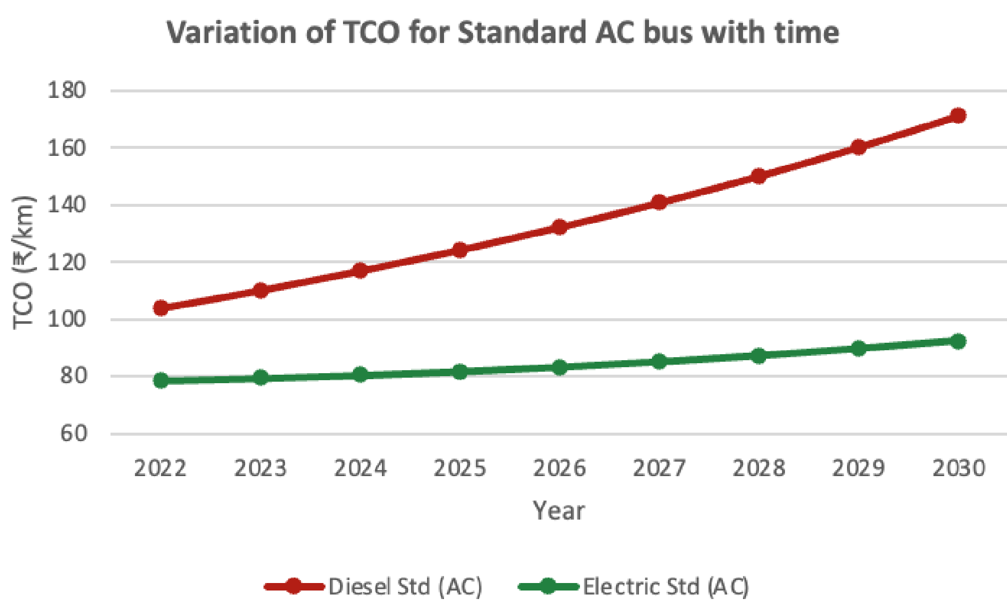

Figure 27: Movement in TCO of 12m Non-AC Diesel and E-Bus with time

It is seen that the electric bus becomes relatively cheaper to operate as compared to the diesel bus progressively. For Standard non-AC buses, the TCO parity is projected to be achieved by the year 2024.

4.3.3. *Different daily usage levels*

The TCO depends on the daily usage of the bus. Since the E-bus has a much higher fixed cost as compared to the Diesel bus, it can be expected to have a relatively lower TCO than the diesel bus as the usage increases. The variation in the TCO with the daily usage is shown in Figure 28 to Figure 30 for the different types of buses.

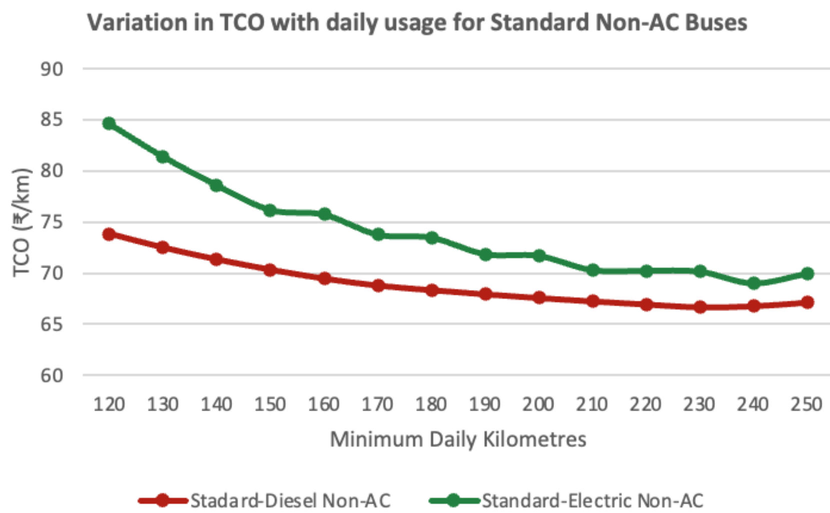

Figure 28: Variation in TCO across daily usage levels for 12m Non-AC buses

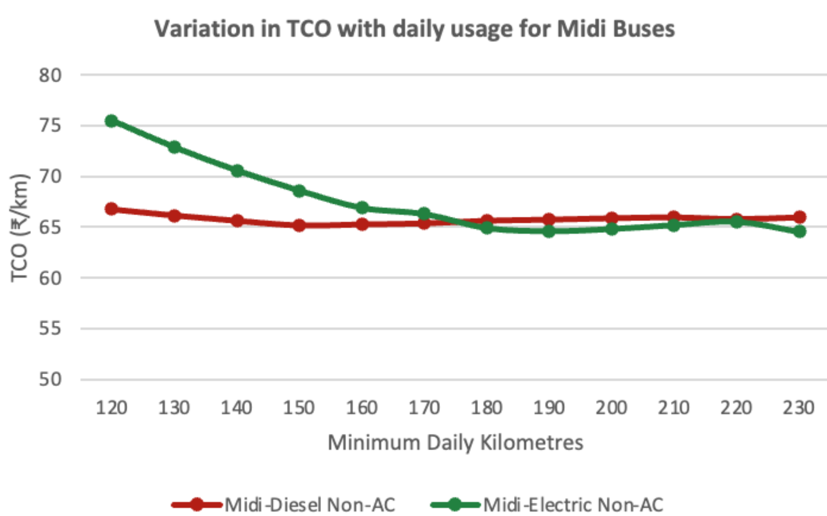

Figure 29: Variation in TCO across daily usage levels for 9m Non-AC buses

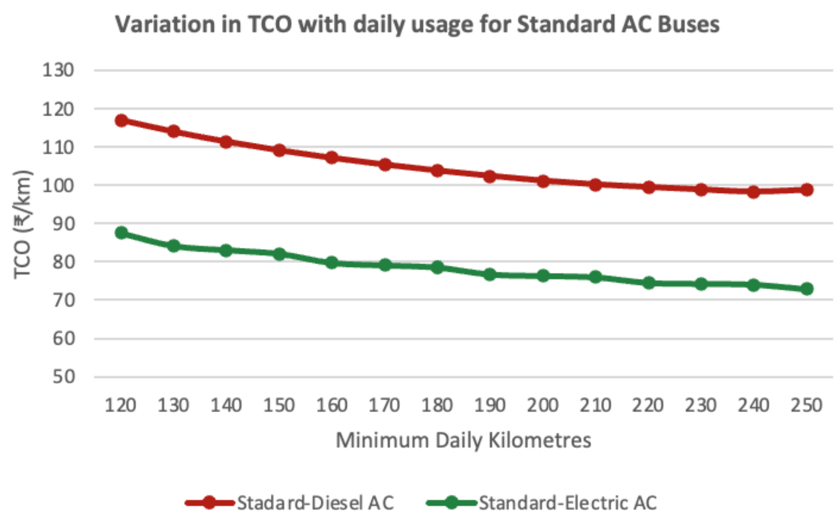

Figure 30: Variation in TCO across daily usage levels for 12m AC buses

4.3.4. With Capital Subsidy

As shown in Figure 28 above, the total cost of operating a standard non-AC diesel bus is lower than operating an electric bus even at very high levels of usage. Therefore, at this stage, there appears to be a need for subsidising the e-bus until the TCO parity is achieved.

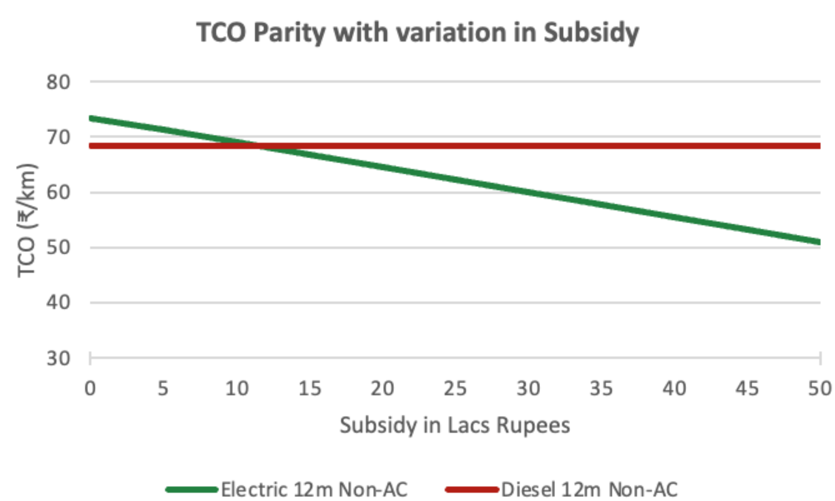

Figure 31: Reduction in TCO of E-bus with capital subsidy for 12m Non-AC bus

It is seen that as per prevailing cost parameters and a daily running of 180 km/day, the TCO parity for the 12m standard bus takes place with a capital subsidy of approximately ₹15 lacs ($19,200).

4.4. Conclusion

It is seen that the TCO of the electric buses is comparable to the diesel buses for the midi and luxury (AC) bus category but in the case of standard non-AC diesel buses, the TCO is higher for the electric buses than for the diesel buses. With time the TCO gap is likely to reduce and TCO parity is expected to be achieved by 2024.

Figure 32: An electric bus supplied by the NTPC-JBM Group joint venture during a trial run in Bengaluru. .Image source - mmj.com

Source - Deccan Herald

05

Service Planning Guide for e-Buses

A systematic approach is needed for the efficient induction and operations of e-buses in any city. Deploying the e-buses without planning could lead to inefficient utilization of the e-buses and other assets, leading to an increased payback period. Based on the successful deployment of e-buses across the globe and in some parts of the country, the following learnings are applicable to any agency transitioning to e-buses:

- Long-term transition plan that includes phasing approach and business models
- TCO analysis at the route level to prioritize route selection
- Infrastructure requirement cannot be an afterthought and needs to be planned at the very beginning. Depot planning and electrical supply infrastructure are important components of e-bus deployment.
- Bus operations are very important that take into consideration battery size, charging strategy and availability of support infrastructure
- Funding sources and business models are important in scaling up the adoption of electric buses.

5.1. Pre-Procurement Phase:

The benefits of electric buses can be increased significantly with meticulous planning and execution. Service providers may have different reasons for adoption of e-buses like lower operating and maintenance costs, meeting emission targets, more reliable performance, etc. Hence, the concerned authority must identify their objectives and prepare a long-term plan for the procurement of electric buses. The transit authority must have the answers to the following questions:

- What is the objective of procuring electric buses?
- Is the authority visioning complete electrification of its fleet?
- How would electric buses improve operational efficiency?
- How would electric buses enhance the commuter experience?
- What would be the timeline for the adoption of electric buses?
- What are the funding sources for procurement?
- What would be the funding sources for operations?

For the induction of e-buses in the fleet, the consideration of the financial parameter is of utmost importance for the STU as well as the operator to smooth operations of the e-bus service.

The financial parameter includes a TCO analysis of the route. TCO takes into consideration both capital and operating costs on a per km basis and helps understand the total cost of the bus over the life of the bus taking into consideration efficiency, battery replacement, running kms annually etc.

5.1.1. *Total Cost of Ownership*

The TCO model utilizes three categories of input parameters — the capital cost, operational cost and vehicle usage details:

- For the capital cost, input parameters include vehicle purchase cost, discount rate, financial incentives applicable, resale value and miscellaneous cost.
- Operational costs comprise of fuel/electricity, maintenance, staff cost and miscellaneous cost.
- For vehicle usage details, parameters considered are the vehicle holding period, average kilometers driven per day, and the number of operational days in a year etc.

Total cost of ownership (TCO) analysis is a basic costs assessment that considers all the direct and indirect costs during a product's lifetime or when the system (project) is over. The advantages of undertaking a TCO analysis for transport agencies include:

- Provides city bus agencies with insights on e-bus performance
- Helps take calculated decisions in selecting the right:
    A. Bus technology
    B. Charging infrastructure
    C. Daily drive distance
    D. Staff deployment
- Determining VGF for e-buses
- Support in preparing a roadmap for electrification of STU

The cost of owning and operating electric buses is primarily dependent on the utilisation (km/day) and life of the bus (years/kms). The daily operating range also dictates the battery size/charging strategy and apparent costs.

Hence, the implementation options arise from the wide range of kilometres covered by the STU's fleet. The relatively high initial and fixed cost of electric buses and low variable cost warrant that these are deployed in the longest schedules.

However, longer operating ranges come with the requirement of larger batteries and/or investment in opportunity charging infrastructure both of which require higher initial investment. The inadequate operating range may mean more than one electric bus is needed to substitute a diesel bus) leading to higher capital and operating expenses.

TERI carried out an analysis of the TCO in Kolkata in 2020[28], the total cost of ownership (TCO) for electric buses was estimated to be ₹45-50/km ($0.58-0.64/km) while the TCO for diesel buses has been found out to be ₹37/km ($0.47/km), considering the capital cost of ₹85 lacs ($109,000) for an AC diesel bus. However, the running cost of the e-buses comes out to be ₹22/km ($0.28/km)which is almost one-third of the same for a diesel bus.

As per the interim report "Improving bankability of e-bus procurement India" TCO analysis was carried out for the FAME – II tenders (for about 2,450 buses). The average Minimum Assured km offered by cities was observed to be 5,600 km per month and the average L1 quoted rate was estimated to be ~₹63.0 ($0.81) per km. For 9m AC e-bus, with Model Concession Agreement (MCA) and generally adopted assumptions, the estimated average TCO could be around ₹70–71 ($0.90-0.91) per km for 9m e-buses with the possibility of ±5% variation.

This is higher than the average discovered rate of ₹63.0 ($0.81) per km. GCC rate according to the formula provided in FAME-II Expression of Interest (EOI) for cities / STUs is estimated to be around ₹54.2 ($0.69) per km. The TCO can be further reduced to ₹57-59 ($0.73-0.76) per km by removing the subsidy bank guarantee, increasing the concession period to be between 10-12 years, access to low interest finance, increasing the daily utilization kms, annual escalation of ~ 3% p.a etc.

[28] *https://iea.blob.core.windows.net/assets/db408b53-276c-47d6-8b05-52e53b1208e1/e-bus-case-study-TERI-Kolkata.pdf*

TCO is found to be relatively more sensitive to the following parameters:

- Minimum assured kms
- Subsidy Bank Guarantee
- Payment Security and Credit Worthiness of the State Transport Undertaking (including setting up of ESCROW account)
- Depot responsibilities
- Electricity Tariff

In India, a majority of infrastructure-related projects are awarded to bidders that quote the lowest price for provision of required goods/ services. However, since the electric bus ecosystem in India (and across the globe) is quite nascent and in flux, Quality-cum-Cost-Based models may be explored for awarding electric bus tenders. The reason for such a suggestion stems from the idea that different models of electric buses are accompanied by different battery chemistries, charging infrastructure, maintenance practices, breakdown susceptibilities, real-world performances, and more. Since transit agencies are yet to develop a sufficient understanding of these factors and the lowest quotes may possibly be accompanied by the inferior quality of service provision (such as limited passenger safeguards with batteries, high degradation of battery capacity, *etc.*), a scope must exist for superior technologies to compete.

Several public transit agencies in India have cancelled e-bus deployment tenders due to the excessively high rates quoted by the bidders. While the capital cost of an e-bus is nearly double the capital cost of a comparable ICE bus, the cost premium for a transit agency operating an e-bus is offset over a 10-year period by the ~50% lower operating and maintenance costs of the e-bus.

Bengaluru Metropolitan Transport Corporation (BMTC) has floated eight electric bus tenders till date (between 9m and 12m buses), of which six were unsuccessful, owing to either presence of a single bidder or high quotes from bidders, both stemming from risk perceptions which impacts the TCO. Certain clauses in electric bus tenders, such as 12-year concession periods in place of 10-years, and staggered release of subsidy bank guarantee, can play a role in limiting procurement costs.

BMTC highlights that it is important to clarify the tender as far as possible, and limit unnecessary risks for bidders in order to get lower quotes and increase the bankability of the project.

BMTC also tried to actively maximize bid participation by intensive pre-bid meetings with multiple bidders, understanding bidders' perspectives, relaxing high battery capacity and driving range requirements, and allowing for opportunity charging during off-peak hours of operation, among others.

In Tamil Nadu, the department believes that the subsidy provided under FAME-II, which is capped at ₹55 lakh ($70,500) per 12-meter bus (costing a minimum of ₹1.2 crore ($154,000)), is not sufficient to catalyze a transition to electric buses, leading to higher operating costs of ₹20/km ($0.26/km) for the transit agencies. Hence, the Government of Tamil Nadu did not proceed with procuring electric buses, despite 525 electric buses being sanctioned by the central government for different transit agencies in the state.

It has been seen in multiple tenders across the country, that the higher the contracted per day per vehicle utilization demand (in kilometers), the lower is per kilometer cost of operating electric buses. Telangana State Road Transport Corporation (TSRTC)'s airport service is a testament to that idea, with one of the lowest costing electric bus operations (₹35.54/km) in the country, as discussed in the earlier section. TSRTC operates about 300-350 kms daily on airport routes. However, this can also be attributed to low per km costs being offered by OEMs as a market capture strategy. The lengths of the routes, in addition to the lower congestion levels on them, help in clocking higher daily running figures for these buses.

West Bengal Transport Corporation (WBTC) preferred the electric buses to be procured through outright purchase during its first procurement, as it aimed to leverage its existing public transport operations infrastructure, manpower and experience. FAME-II scheme mandates procurement through the gross cost contracting model, wherein subsidies are not awarded for outright purchases and is thereby not conducive to WBTC's purposes.

Further, the cost of procurement in the gross cost contracting model was considerably higher as compared to the outright purchase model, which also led to the cancellation of a tender for 100 electric buses under the FAME-II.

An e-bus consumes less energy per kilometer as compared to a congested (or low-speed) route. Precisely, deployment of an e-bus on a high-speed route is found to consume 25-30% less energy than its deployment on a low-speed route Hence, deployment of electric buses on inter-city or low congestion urban routes, such as airport routes, is expected to cost less than otherwise.

Ahmedabad Janmarg Limited (AJL)'s past experiences with gross cost contracting informed multiple clauses including reasonable caps on delay penalties; longer concession periods; bearing of electricity costs; inclusion of Force Majeure clause in bid documents; detailed escrow mechanism, and; acceptable fee escalation formulae in their electric bus tendering exercise, has helped to reduce ambiguity for the bidders. Consequently, the bidders avoided front loading costs stemming from assumed risks in their bid prices, which led to some of the best-priced bids in the country (nearly ₹55/km ($0.71/km)). The Chief Minister Bus Scheme in Gujarat offers viability gap funding of up ₹12.5/km ($0.16/km), to public transit agencies for all bus-based transit operations. This helped in reducing electric bus procurement costs by nearly 25%, and made their operations cheaper than those of diesel buses.

Route level TCO analysis is helpful in determining the actual comparison of electric buses with their ICE counterparts. Daily utilization kms, dead kms (to/from the depot) and charging strategies specific to a route can be planned and various scenarios can be then evaluated to determine the TCO.

5.1.2. Route Selection and Evaluation

Route selection is one of the most important factors in the implementation of electric bus routes as the route planning for e-buses is different from conventional buses. Factors such as the number of stops, depot locations, the peak and off-peak frequencies, the size of the fleet and route characteristics play an important role in optimizing charging solutions and operations of e-buses and have a bearing on the total cost incurred.

One of the important concerns for transit agencies and operators is that bus electrification should not affect existing operations like route alignment or timetables. The success of the e-buses is determined by the routes selected for operations.

E-buses are heavily dependent on the charging infrastructure and hence, authorities should determine the routes for operations before the deployment. Several transit agencies have the following questions while planning for electric bus deployment:

a. What is the effective range for the particular route taking into consideration reserve SoC and other losses due to passenger loading and air-conditioning?
b. What are the technical specifications (battery size/capacity) and performance of the buses (energy consumption)?
c. Is the deployment of electric buses going to increase the cost per km?
d. Will it be easy to accommodate the crew schedule and still complete the daily targeted kms along the route?

Routes that can utilize the depots should be selected for electrification and routes should be selected depot by depot to ensure focused investments. Hence, routes currently utilizing those depots or those that can be re-routed to the depots selected should be identified. The higher the number of schedules in a depot/terminal, the more effective will be the utilization of charging infrastructure.

The parameters for evaluation, their definition and their importance while deploying electric buses are explained in Table 3 below.

Table 3: Criteria for Evaluation of Routes

Key Criteria	Definition	Relevance
Effective Kms	Total revenue earning distance of a schedule per day	a. The range of e-buses currently in the market is up to 230 kms. The selected routes shall ensure full utilization of the battery and eliminate the need for opportunity charging. b. The battery capacity will decrease over the lifetime. Hence, if we select only higher utilization routes, more buses would be required for the same service supply in the future or opportunity charging would need to be planned. c. The routes with effective kms 180-230 kms are found to have a lower replacement ratio for e-buses with bigger battery capacities (>300 kWh) hence can be given the highest priority.
Total Cost of Ownership	Total cost taking into consideration capital cost, operating costs, and maintenance costs over the life of the bus or the concession time period.	The TCO difference between the electric buses and diesel buses along the specific routes is minimal and cost parity can be achieved through subsidies from the central or state.

Number of schedules across selected depots	The routes to be deployed shall have at least one schedule that utilizes or can be rescheduled through one of the selected depots	In order to ensure focused investment and implementation efforts, depots for electrification are selected first. Therefore, the routes that need to utilize these depots currently or could be rescheduled through the selected depots with minimum dead kilometers should be prioritised.
Operational Efficiency	The operational convenience in placing the electric buses along the route	Easy adaption of the new schedules along the routes
Geographical Coverage	The coverage of routes based on the primary land use it is connecting	a. Qualitative parameter for evaluating major user category b. Preference could be given to the high-density areas, major employment hubs, areas, connectivity to metro stations etc

DTC's (Delhi Transport Corporation- the public bus operator in Delhi) did an analysis of Delhi's routes, and found that it is not feasible to deploy electric buses in the same way as conventional fuel buses. Precisely, electric buses may require more shift changeover/layover downtime for operations to be feasible or may require buffer fleet support during opportunity charging hours and more. Hence, for all future tenders, DTC is contemplating to carry out a system-wide route analysis, the pertinent results of which can feature in the tenders as tentative information to bidders for electric bus deployment. The same may help bidders to be more precise in quoting their rates, and also help DTC avoid any operational and performance-related challenges.

DTC, in order to gauge the feasibility of operations of electric buses on select routes, deployed prototype buses on them. The same can help the transit agency to understand the energy consumption pattern for an electric bus in Delhi's operating conditions, and test routes before large-scale operations commence.

At a citywide scale, the route selection can also be approached for optimising the capex and the opex. Based on that the following options could be evaluated:

A. **Option 1**: Minimising Capex by electrification of schedules covering least daily operating kilometres first and longer schedules in subsequent phases.
B. **Option 2**: Minimising Opex by electrification of schedules having most daily operating kilometres first and shorter schedules in subsequent phases.
C. **Option 3**: Optimising Capex and Opex: A mixed approach i.e. electrification of medium range schedules first, followed by longer schedules and then shortest schedules.

Table 4: Number of routes on which e-buses have been deployed

City	Number of Routes deployed
Kolkata	12 routes (9m and 12m)
Pune & Pimpri-Chinchwad	19 routes (9m and 12m)
Bengaluru	11 routes (9m buses)
Delhi	19 routes (12m buses)
Hyderabad	4 routes (12m buses)

Evaluation of Routes:

Replacement Ratio

Replacement ratio is the ratio of the number of e-buses required to the number of conventional buses to provide the same level of service. The route selected should minimize the replacement ratio so that the number of electric buses required to replace the diesel buses would remain the same. Since an electric bus is not equivalent to a diesel bus due to the need for charging once the battery is discharged, the routes should be selected in such a way that one electric bus can replace one diesel bus.

Because of inefficient planning of routes, the replacement ratio for electric buses can be more than 1 i.e., requiring more electric buses to replace the current ICE buses. Determining the route-wise replacement ratio in the initial stages can bring down the overall replacement ratio and consequently, the costs.

For the routes with effective vehicle utilization per day of more than 180 kms, the current range of e-buses per full-charge for 12m buses is up to 200 kms at 80% SoC, which may decrease over the life cycle of batteries. Therefore, it is essential that the selected routes and the associated crew shift allocation would ensure full utilization of a battery charge.

For routes, where the average vehicle utilization is more than 200 kms, intermittent charging at airport/depot can be arranged to ensure a minimum replacement ratio. For other services, effective vehicle utilization per day within the range of 180-220 kms is preferred. This will eliminate the need for additional charging during its operation time in a day. However, in later years of operation, opportunity charging would be required.

In PMPML's case, the electric buses are able to fulfill the km/bus/day as per PMPML's requirement. Currently, the minimum assured kilometres for the electric bus operator is 225 km per bus per day which is more than the current average kilometres per bus per day for ICE buses (207.8). The electric buses were thus able to replace the PMPML's ICE buses with some top-up in between the existing schedules.

The kilometers travelled per bus per day (km/bus/day) for a 9m electric bus in Nigadi depot is 229 km, which is equal to the 12-meter buses in Bhekrainagar depot. This suggests that 9m buses in Nigadi depot have been able to get a longer range than 9m buses in Bhekrainagar Depot. 12m buses in Bhekrainagar Depot, however, have only been operated for 182 km per day - which is far below the average km/bus/day for ICE buses. In conclusion, there is still scope for better route selection and planning for electric buses by PMPML.

Case Study

Route level drive cycles

A study by International Council on Clean Transportation[29] (ICCT) involved route-level simulations for Bangalore Metropolitan Transport Corporation (BMTC) to estimate the route-level energy consumption of electric buses. Drive cycles were developed using six metrics - average driving speed, the standard deviation of driving speed, characteristic acceleration, average positive road grade, the standard deviation of the road grade and route mean square error. This method can take route-level factors into consideration for optimal route selection.

Route level Total Cost of Ownership for most optimal replacement ratio

Route level drive cycle assessment can be useful for identifying routes that can have a replacement ratio of 1:1. In this study[30] ICCT developed drive cycles and compared the TCO of electric buses on those routes. The TCO parity for airport routes was found to be the highest as compared to other routes. Airport routes were also observed to have higher bus utilization than the range of the electric buses suggesting the need for opportunity charging. Electric buses on route numbers such as V-201R, and V-335EK would be able to operate throughout the day without the need for opportunity charging even after battery degradation. They also have a lower TCO than diesel buses (TCO Parity < 1)

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[29] ICCT (2020). Strategies for deploying zero-emission bus fleets: Development of real-world drive cycles to simulate zero-emission technologies along existing bus routes

[30] International Council on Clean Transportation (2020). Route-level modeling to support zero emission electric bus deployment in Bangalore. Presented in the webinar for Climate and Clean Air Coalition by Tim Dallmann on 9 April, 2020

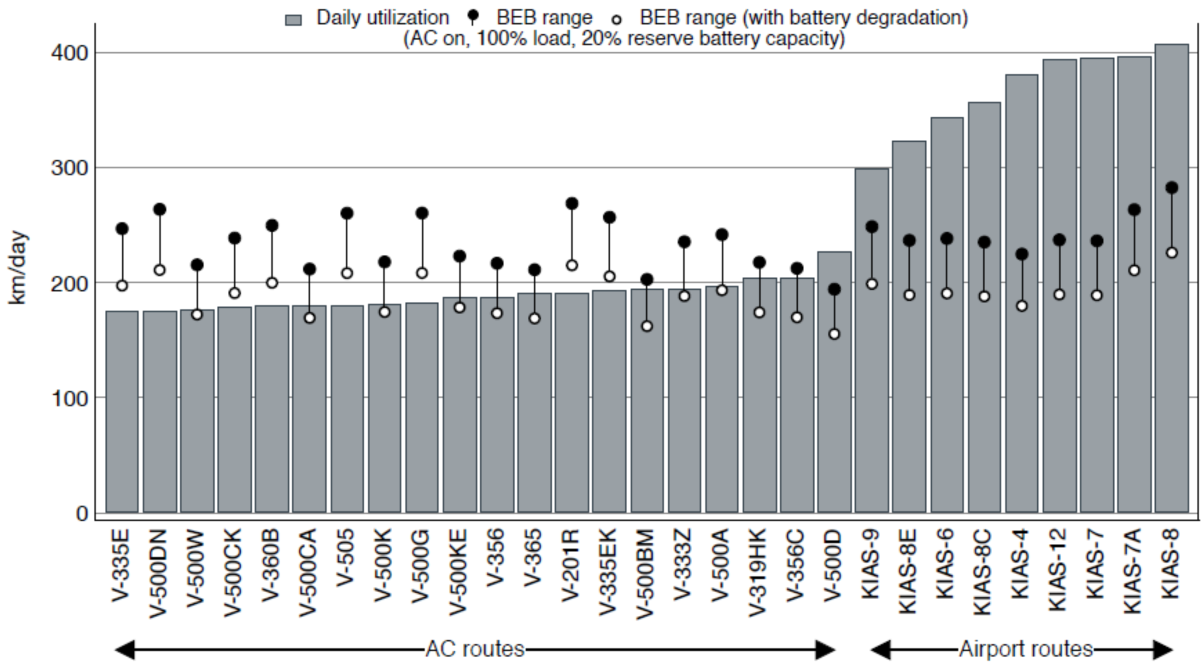

Figure 33: Estimation of replacement ratio by comparing estimated range and daily utilization (ICCT, 2020)

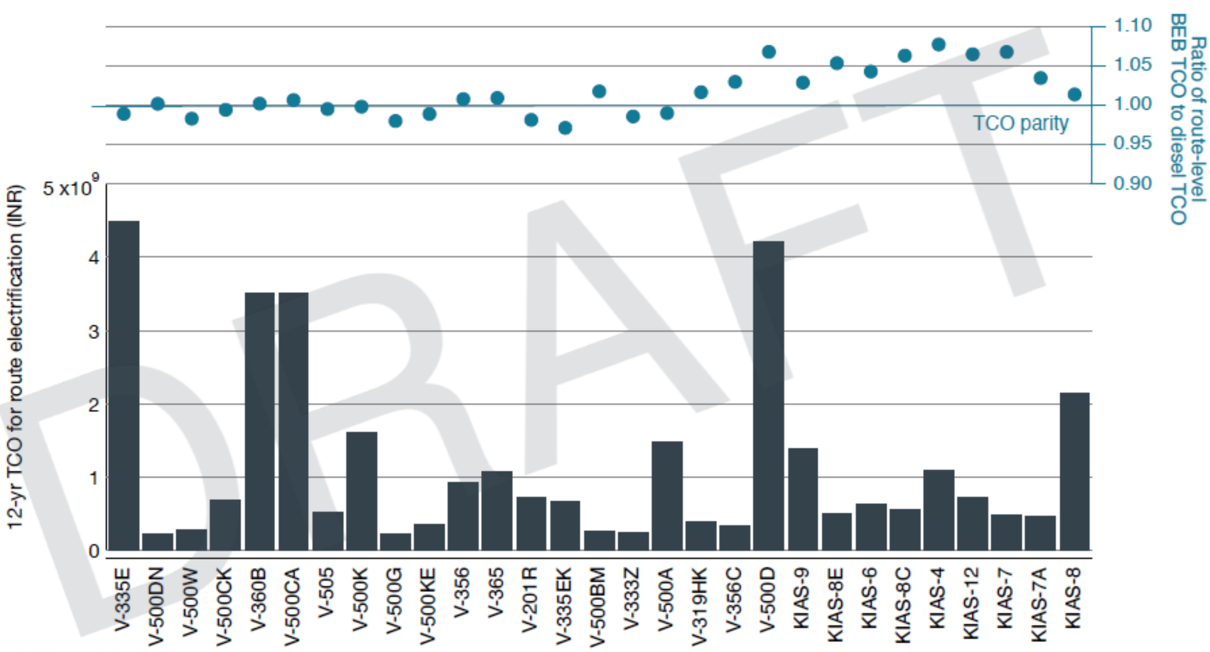

Figure 34: Estimation of TCO for electric buses (ICCT, 2020)

Coverage vs Ridership

Route selection based on ridership refers to prioritizing routes with high ridership; route selection based on coverage refers to prioritising the coverage of a larger geographical area (including suburbs).

Selection of routes with high ridership ensures that the benefits of the electric buses- such as lower noise, less vibrations, lower trip cancellation rate, zero emissions, etc. - can be enjoyed by a maximum number of commuters. The electric buses also have a lower kilometer cancellation rate which makes them more reliable.

Operators should prioritise routes with consistent and predictable ridership to make the most efficient use of the battery. A predictable ridership means the predictable load on the bus and predictable battery usage. Prioritizing high-demand routes in densely populated areas require a lower cost. Studies like ITDP's People-Near-Transit[31] analysis can help operators in route selection, targeting densely populated areas.

A major disadvantage of selecting coverage over ridership is the requirement of additional charging stations due to longer routes in sparsely populated areas.

Congested routes vs non-congested routes

Electric buses are suitable for operating on both congested and non-congested routes. ICE vehicles burn fuel when idling and have very poor efficiency at low speeds; electric buses, on the other hand, consume a negligible amount of energy when stationary, and have comparatively better efficiency at low speeds - especially in stop-and-go traffic conditions[32].

BRT routes have predictable traffic conditions and operating speed and minimum idling. ICE buses can thus be deployed on BRT routes and electric buses would have a significant advantage in mixed traffic lanes.

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[31] *https://www.itdp.in/resource/people-near-transit-transit-near-people/*

[32] *Bigazzi and Clifton (2015), Modeling the effects of congestion on fuel economy for advanced powertrain vehicles, Transportation Planning and Technology*

Terrain

The upward gradient requires higher battery consumption, but the downward gradient can make up for some of the battery losses as battery consumption is lower when electric vehicles are climbing down the slope[33]. The main advantage of electric buses over ICE buses is the regenerative braking - the ability to recharge the battery when the bus is on a downward gradient. The electric buses already have lower energy consumption, and regenerative braking can further reduce the net energy consumption as compared to ICE buses on a downward gradient.

Route level simulations should be carried out to identify the most feasible routes for electric buses in areas with rolling terrain.

Multiple routes vs Single route electrification

PMPML has 19 different routes assigned for the operation of electric buses. These routes also have diesel/CNG buses operating on them that do not have air-conditioning. As a result, passengers wait for air-conditioned electric buses. PMPML is thus facing the problem of overloading on their electric buses (more commuters boarding the bus than its capacity). The number of passengers per bus per day on electric buses is 35% higher than on ICE buses due to air-conditioned services at the same fare. Hyderabad in contrast operates electric buses only on the airport route and is able to achieve better operational efficiency.

Hence, route-wise electrification can be an effective strategy for optimal utilisation of the electric buses, charging infrastructure and investments.

In conclusion, routes should be very carefully selected for electric bus operation in order to optimize operations. A route-wise replacement ratio can help the transit authority to switch to electric buses with minimum route re-structuring and disruption in normal operations. All the factors listed above should be considered for optimal utilization of electric buses.

[33] *Liu, Yamamoto and Morikawa (2017), Impact of road gradient on energy consumption of electric Vehicles, Transportation Research Part D*

5.1.3. Depot Location and Planning

During the deployment of electric buses, several cities will experience challenges related to availability of space at existing bus depots, as space was needed for parking and maneuvering of buses, development of grid infrastructure, and setting up of chargers/ swapping stations. The approach for depot and route planning is to ensure that these challenges are addressed and the investment is aligned with the implementation efforts. Therefore, many cities are selecting the depots first and then the routes utilizing those depots are selected. This would eliminate the need for development of supporting infrastructure at all depots, if routes are selected first then it is important to ensure that there would be maximum utilization of depots selected. Following sections discuss on depot selection criteria and route planning for electric buses. The criteria for depot selection are as follows:

- Depots with minimum electricity infrastructure cost
- Depots with maximum utilization of charging infrastructure
- Depot location selection to reduce dead mileage
- Size of the depot including space availability in the depot for expansion

Fringe or city center

Depot charging requires large spaces to set up charging stations. Hence, the fringes are most appropriate for the depots. However, the location should not lead to an increase in the dead kilometers. Opportunity charging stations can be set up in the city center to increase the range of the bus.

Installation of charging infrastructure in densely populated or high-demand areas (such as central business districts) from where multiple routes pass provides a significant advantage by increasing the utility of the infrastructure[34].

Minimize dead kilometres

The depot locations should be as close as possible to the terminals to minimize dead kilometres. The component of dead kilometres should be considered during route planning. For example, the bus depots in Pune are within 100 meters of the terminals which ensures negligible dead kilometres.

[34] *Mountain-Plains Consortium (2018), Strategic Planning and Design for Electric Bus Systems*

Space requirement and Topography

Transit authorities in India park their buses in blocks (clusters) to save space. This approximately saves 50% of the parking space[35]. Diesel and CNG buses require about 56.1 sq.m of space per bus (for parking and refuelling infrastructure).

The electric buses require access to the bays along the charging infrastructure, hence more area would be required. Assuming one charging station for four electric buses, 25% of the buses would be parked at the charging bays and rest 75% of the electric buses can be parked in blocks - such a setup would require approximately 64 sq.m/bus (14% more than diesel/CNG buses parked in blocks). If all the electric buses are provided designated bays (without forming blocks), an area of 90 sq.m/bus would be required[36] (61% more than diesel/CNG buses parked in blocks).

The depot layout design should take into consideration the following are:

1. Area required for one bus including depot requirements, such as parking, workshops, staff amenities, administrative block etc. 150 sq.m
2. 40% buses are always out for operations. It varies from city to city about 20-50% of buses are night out shifts and anywhere between 50%-80% are parked in the depot during night time
3. Charging assumed slow charging (75kVA) requiring 6 hours of charge
4. Further, the depot layout would be finalized later based on the charging infrastructure procured as per the OEM.

[35] *All parking area requirements computed from - SG Architects (2017). Bus Depot Design Guidelines*
[36] *Assuming 60 degree angular parking*

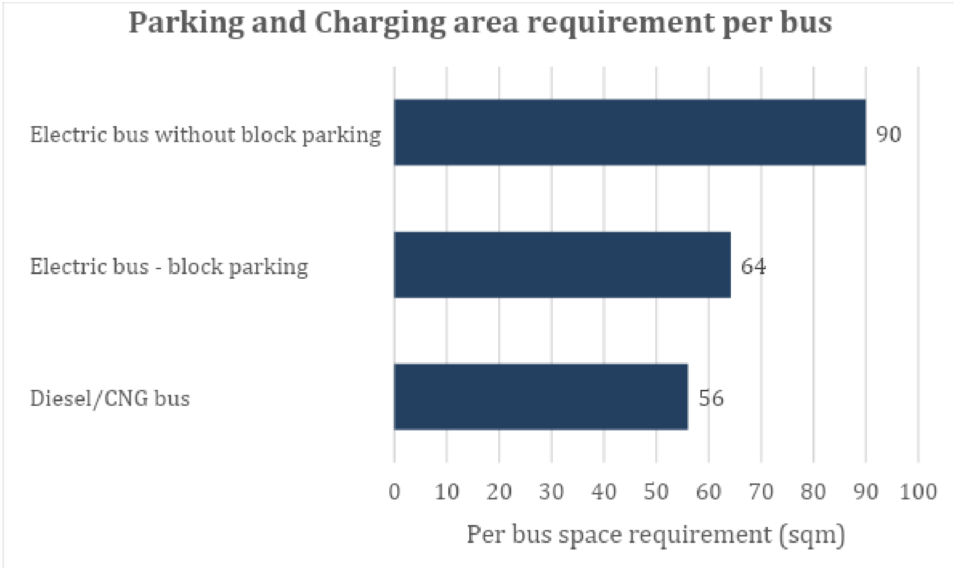

Figure 35: Parking and refuelling area per bus for ICE and electric buses.

Depot location should also be topographically strategic with an efficient water drainage system to avoid water logging that could potentially harm the charging equipment as well as the electrical components of the buses.

Figure 36: An example of block parking used in a bus depot in Dubai (Source: The Khaleej Times)[37]

[37] *Khaleej Times (2020), RTA completes new bus depot to meet Expo needs*

Dearth of land is common in Mumbai, and effects of the same trickle down to development of electric bus depots also. In case of one of BEST's depots (in Colaba), spatial constraints did not allow for establishment of four units of 1250 kVA conventional distribution transformers. Consequently, BEST had to procure specially designed compact distribution transformers, which took up 75% less area.

Depots with minimum electricity infrastructure cost: Understanding electrical limitations as well as the local distribution system is necessary for the long-term deployment of electric buses. The current and future energy demand indicated at few depots the existing electricity infrastructure only needs a slight upgradation, while at few others, sub-transmission lines and sub-stations needs to be provided at the depots. The evaluation of the current electricity infrastructure facilities at the depots and at the terminals should be carried out. Further, en-route charging may be evaluated in detail to optimize the location, ensuring that the location is adequate for charging with sufficient charging time and easements can be obtained.

Depots with maximum utilization of charging infrastructure: In Kolkata, electric buses were being charged irrespective of load demand variations through the day. Hence, WBTC anticipates that city-level peak power requirement might surge if a large fraction of its fleet is converted to electric. To mitigate the same, it aims to explore smart charging opportunities and support the implementation of time-of-day or time-of-use tariff schemes.

For electrifying bus routes, the depot identification process must consider the power infrastructure surrounding it. As per BMTC, the best strategy is to select depots as close as possible to electrical substations (which have power capacity available to support requisite level of electric bus charging). This is important as the cost of drawing an 11 kV line extends up to ₹1 crore/km ($128,200/km) for the STU. Here, a fine balance between locating close to substations and being closer to route terminals must be struck.

Depots are also important as charging and maintenance of the buses happen here. Maintaining e-buses requires dedicated infrastructure, as maintenance practices are either daily, weekly, or intermittent in nature. The daily maintenance practices are less extensive than the weekly and intermittent ones, and are quickly carried out post the daily transit operations, during in-shedding.

Weekly and intermittent practices, on the other hand, require a detailed inspection of the e-bus, and must not hinder the operations and manoeuvrability of other buses and activities within a bus depot. Therefore, dedicated space and infrastructure is needed within a depot for e-bus maintenance, as depicted schematically in Figure 37 below.

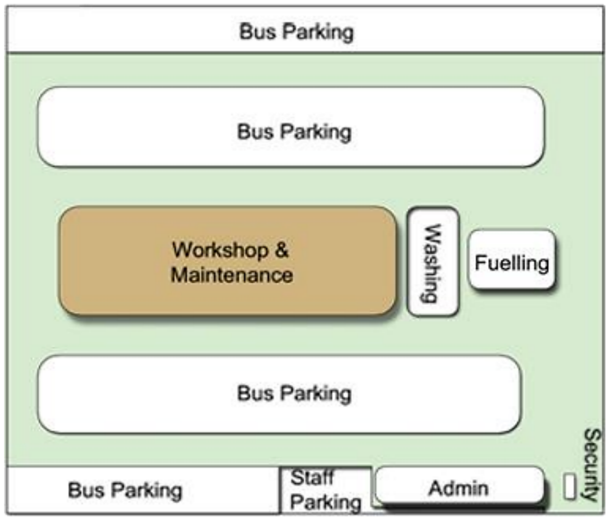

Figure 37:Schematic diagram of a bus depot highlighting the positioning of maintenance area

5.1.4. Charging technology

Charging setup for e-bus fleet comprises charging solution (associated equipment) and associated power infrastructure. The charging solution for electric buses is an important part of transition and is one of the critical steps both in the planning and operations of the buses. E-bus operators should employ different charging strategies to manage the charging demand of e-buses.

City bus operations occur typically between 5am-11pm. In the case of e-bus fleets, this overnight time is often utilized for charging. As about 6 to 8 hours of time is available for charging during this time, operators charge all the e-buses in the fleet to the full battery capacities to make them ready for the next-day duty cycle. Generally, operators do slow charging and the low-power chargers that are comparatively less expensive are suitable.

Depot charging gives a significant advantage in terms of freedom for navigation, route selection, and lower range anxiety, but makes batteries heavier leading to lower passenger carrying capacity. Depot charging is best suitable if:

a. A high capacity grid connection cannot be established
b. Transit authority deems freedom of route selection for operation to be more important
c. Setting up of infrastructure for opportunity charging is a constraint
d. Traffic conditions are not predictable in the city

Opportunity charging requires charging stations at regular intervals which reduces the freedom of navigation and could lead to higher infrastructure cost. Opportunity charging is best suitable if:

a. A high capacity grid connection for fast chargers with 450kW to 600kW rated capacity can be established
b. Transit authority deems higher passenger capacity per bus to be more important
c. Space is available for opportunity charging infrastructure such as pantographs
d. Traffic conditions are predictable on the route or a dedicated corridor is available for operation of electric buses (such as in bus rapid transit or bus priority lanes)

Some of the important considerations for decision on charging technology[38]:

a. **Length of a trip**: Opportunity charging stations need to be installed if the length of the trip is longer than the range. For relatively smaller trips, depot charging can be used.
b. **Turning time (layover time):** If layovers are less than five minutes at the terminals, opportunity charging cannot be relied upon. A fast charger with a 150kW charging rate can provide enough charge for a 12m bus to run up to nine extra kilometers in five minutes. A charger with 600kW capacity can provide enough charge for the same bus to run up to 36 extra kilometers - but they can put a heavy load on to the grid[39].
c. **Delays:** Irregularities in the schedules due to factors like unpredictable traffic conditions can affect available charging time. In such cases depot charging is preferable.

[38] *Siemens (February, 2020). Accelerating bus fleet electrification*
[39] *Assuming that the bus consumes 1.3 kWh of battery per kilometer of operation.*

d. **Connection capacity at terminal stations:** Opportunity charging requires fast-charging infrastructure which usually operates from 300kW to 600kW (never less than 150kW). Hence, a high capacity is needed.
e. **Depot capacity:** One depot can support upto 150 buses using a load management system. More buses would require even higher grid capacity which can significantly drive the costs up.

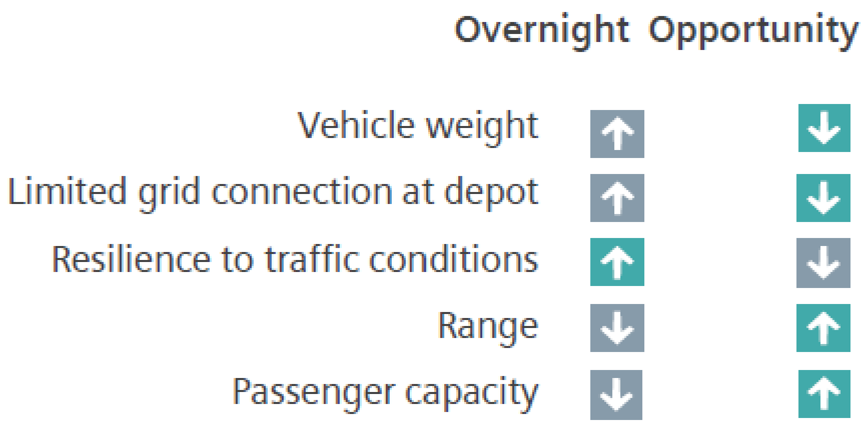

Figure 38: Comparison of overnight (depot) charging and opportunity charging (Source: Siemens)

In Delhi, provision of power of the order needed for electric bus operations (>4 MVA) is proving to be a challenging task. Hence, the transit agencies in Delhi have prioritized their depots for commencing electric bus operation in coming years, based on the timelines communicated to them by relevant power distribution companies - for provision of a required level of power connection (if at all possible). In addition, given the lack of terminal spaces available the plan is to stick to overnight charging at depots as much as possible.

In Pune, PMPML's early experiences of electric bus operations were not smooth owing to electrical faults in their Bhekarai Nagar depot which damaged two distribution transformers. Hence, a study on their upstream electrical infrastructure was carried out by Maharashtra Electricity Distribution Company Limited, which highlighted that lack of staggered charging practices overloaded the feeder line.

Therefore, either dedicated feeder lines (of 11 or 22 kV) must be provided for electric bus depots, or staggered charging practices monitored by Power Quality Meters and Load Profile Analyzers should be adopted.

The 9 meter electric buses in Pune have a far lower range than required. They are recharged during the layovers in the depots using fast chargers and thus rely heavily on opportunity charging. The analysis of Pune data showed that 45% of the electricity units have been consumed during the day (opportunity charging) when the rate of electricity is higher. 12-meter electric buses have only consumed 10.75% of the electricity units during the day which shows higher reliance on depot charging.

Cities like Kolkata and Hyderabad that deployed electric buses under FAME-I, did not clearly plan for opportunity charging. Infact, Kolkata added a fast charger much later after the deployment of the e-buses. But cities that have started deploying electric buses under Fame II, have planned well for the charging strategies. They have opted for higher power ratings and the chargers can be used for both overnight and opportunity charging.

Table 5: Charger Rating in various Indian cities

City	Charger Power Rating
Kolkata	60 kW (for overnight charging) 120 kW (for opportunity charging)
Mumbai	80 kW (for overnight charging) 150 kW (for opportunity charging) 240 kW (for overnight and opportunity charging)
Pune	80 kW (50 units for overnight charging) 150 kW (1 unit for opportunity charging)
Bengaluru	200 kW (for overnight and opportunity charging)
Delhi	200 kW and 240 kW (for overnight and opportunity charging)
Hyderabad	80 kW (for overnight and opportunity charging)

5.1.5. *Charging Strategy*

The operator deployed one of the below-mentioned three strategies for charging.

- **Overnight Charging only at Depots** – When the battery capacity gives enough range (kms) that can cover the daily kms of a bus then overnight charging is sufficient. Typically, overnight charging is done with slow chargers given the availability of a definite window of time for charging during the night times. Battery packs are charged to their full capacity to meet the daily requirement. This scenario results in low cost of chargers but possibly increased battery weight and eventually lower passenger capacity of the bus. This scenario may lead to a greater depth of discharge and can accelerate battery degradation. However, slow overnight charging is also known to increase battery life. Additionally, an extra fleet may be required to cover high-demand corridors.

- **Overnight Charging and Opportunity Charging at Depots** – Typically buses in major cities travel anywhere between 150-250 kms on a daily basis. Many times services are curtailed during off-peak periods in mid-day. Due to the availability of enough overlay time buses can be charged during this time. This enables operators to choose a smaller size of the battery. Buses can come back to the depot for additional charging during off-peak hours in the daytime. The same chargers can be used for both overnight and opportunity charging by appropriate selection of charger power.

- **Overnight charging at Depots and Opportunity Charging at Terminals or En-route** – In this scenario instead of buses going back to depots they can be charged en-route or at terminals. This is because many times depots may be located far away and could result in additional kms known as dead kms (distance between the depot and actual starting point of the route). Higher dead kms result in reduced energy available for actual travel along the route and reduce the performance of buses. Opportunity charging en route not only helps in reducing the battery size but also provides much-needed flexibility. Typically opportunity charging at terminals/en-route uses fast chargers.

Opportunity charging requires additional charging infrastructure outside the bus depots (charging stations with high charging power), which makes the implementation significantly more complex and expensive.

Figure 39 below gives general guidance for the selection of the charging strategy based on the storage capacity of the battery and the distance travelled per day by an E-bus.

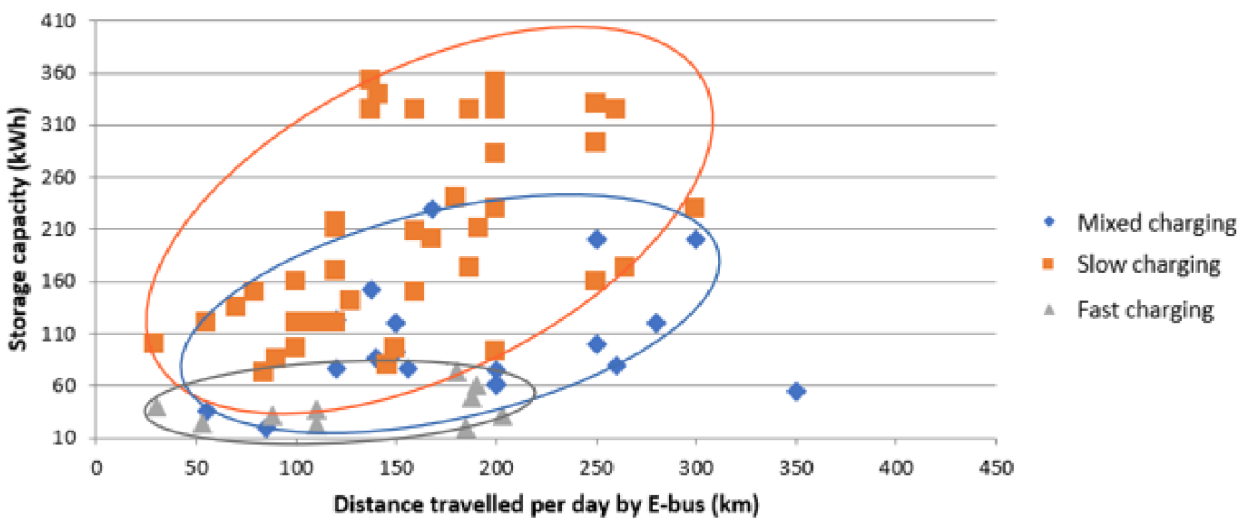

Figure 39: Charging strategy based on battery capacity and daily distance travelled by E-bus (Source: Manufacturers and UITP)

Charging strategies are dependent upon several factors as discussed below:

- Time to charge an e- bus varies and depends on a range of factors including the charging technology and the power rating of the charger.
- The charging time and power are dependent on the battery chemistry that has been used. Currently, three battery chemistries are used for electric buses – LFP, NMC and LTO. The first two being dominantly used for deploying e-buses in Europe and Asia. NMC batteries have high energy density and lower lifetime when compared to LFP batteries and this significantly impacts the charging time.
  - o LFP is the most reliable battery chemistry and can be used with slow charging systems with a charging rate not more than 0.7 C. LFP technology offers slower battery degradation and longer life cycles when handled properly.

  - NMC batteries offer a faster charging rate (possibly up to 2 C rate), as well as larger capacity and are suitable for both opportunity charging and overnight charging.
  - LTO offers higher charging rates than LFP and NMC but has much lower energy density. This is more suitable for flash or ultra-fast charging with frequent en-route charging opportunities.
- Charging time is dependent on the daily running kms (including dead kms) of an e-bus and the desired level of service of the bus operations.

  Factors like the total frequency of buses and overlay time at the terminals impact the total number of trips which in turn impacts the charging strategy.

Charging strategy is impacted by the time taken to fully charge an e-bus and its impact on downtime for the vehicle and the space availability for charging infrastructure and parking of buses at depots and terminals.

The figure below provides a simple approach to charging. For each schedule in the timetable of the route, a bus with maximum charge is dispatched. Every incoming bus is scheduled for charging if the SoC falls below a certain threshold, else it is idle during the layover. Buses which are waiting at the layover are also scheduled for charging based on charger availability and the next dispatch time. An optimum number of chargers at one or both terminals can be calculated typically using an optimizing algorithm so as to maintain the SoC level of the buses above a minimum value of 20%.

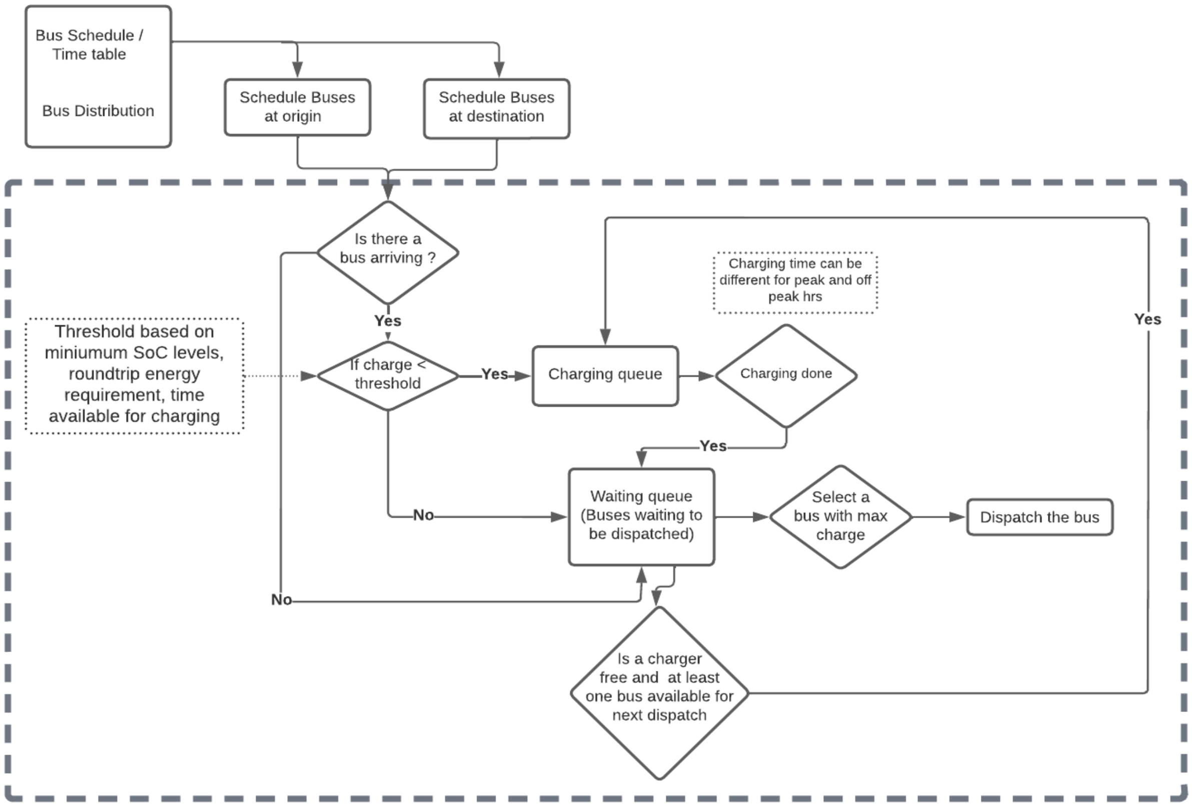

Figure 40: Flow chart showing the approach to charging electric buses

Manual management of electric bus charging can lead to sub-optimal usage of electric buses. Another level of complexity that the transit operators inevitably face is the management of the mixed fleets (in terms of bus size and technology).

Software plays a very important role in electric mobility. Due to the high upfront cost of the infrastructure and the battery, it is important to optimize the charging and scheduling process. The number of chargers is lower than the number of electric buses for optimal usage of the infrastructure and to avoid overload on the grid. Shenzhen, for example, has one charging station for every three electric buses.

Intelligent planning and scheduling solutions are available in the market which can optimize the charging process of the electric buses for different battery sizes and using a combination of slow and fast charging processes. Such tools can also elongate the life of the battery pack and optimize its overall usage.

5.1.6. *Charging Optimization*

Electric buses are less flexible than their diesel counterparts due to their limited driving range and recharging times. Therefore, scheduling electric buses adds further operational difficulties. Additionally, various labor regulations challenge public transport companies to find a cost-efficient crew schedule. Vehicle and crew scheduling problems essentially define the cost of operations. Factors affecting the standard battery recharge and discharge rates need to be understood. Charge level information is required so that operations teams can ensure service levels are maintained and charging requirements can be managed. Thus, scheduling needs to take into consideration the labor regulations applicable to the crew, the need for opportunity charging and the service level to be provided (frequency of service etc.). These need to be optimized by minimizing the cost of operations.

As per the MV Act, provision for Daily intervals for rest includes:

(1) The hours of work in relation to adult motor transport workers on each day shall be so fixed that no period of work shall exceed five hours and that no such motor transport worker shall work for more than five hours before he has had on interval for rest for at least half-an-hour; Provided that the provisions of this sub-section in so far as they relate to interval for rest shall not apply to a motor transport worker who is not required to work for more than six hours on that day.

(2) The hours of work on each day shall be so fixed that a motor transport worker is allowed a period of rest of at least nine consecutive hours between the termination of duty on any one day and the commencement of duty on the next following day.

Thus, for electric buses, the crew rest period should be matched with the opportunity charging time at the terminal and the schedule should be accordingly prepared. While buses are typically charged when they reach an SoC of 20% but in this case, buses can be charged (for opportunity charging) based on the daily energy requirement after taking into consideration various losses. When often analyzing the right charging strategy for multiple buses on a route, it becomes imperative to look for a solution that optimizes the number of fast chargers. Typically, without proper planning, fleets end up with unmanaged charging which involves charging most of the buses during the same time during off-peak hours. This leads to a two-fold problem- an increase in the number of charger requirements and also an increase in the peak energy demand on the utility grid which in turn may raise the electricity cost by attracting demand charges and time of use tariffs from the utility service provider.

Determining the number of chargers is not a linear solution. It requires an optimizing algorithm by considering various factors such as the required bus schedule, battery size, charger rating, crew shifts and rest hours, and other route parameters.

- Route parameters such as route length, number of buses, round trip time, and layover times
- Battery parameters which include battery capacity, efficiency, and route energy for the battery size.
- Bus operational parameters which include the schedule, peak and off-peak hours, and bus distribution at the terminals
- Charger parameters which include Fast charger power and available time intervals for charging
- Crew schedule including rest times and shift hours

Figure 41 below indicates a representative figure of the charging taking into consideration the above parameters.

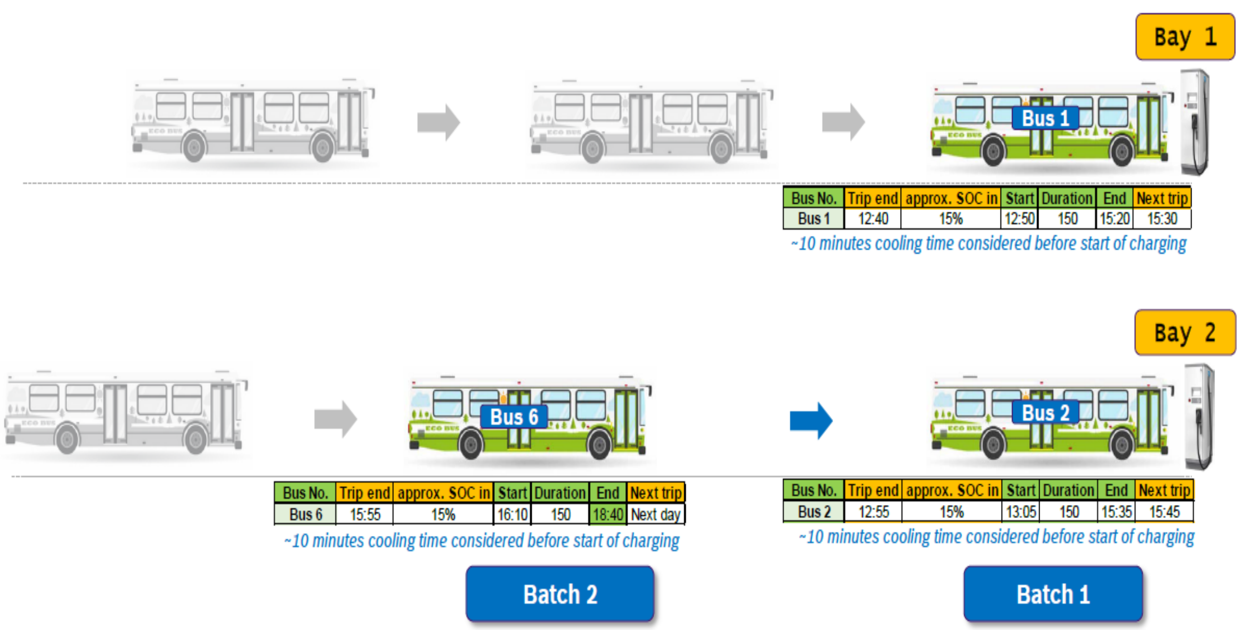

Figure 41: Illustration considering various parameters for charging of electric buses

5.2. Post-Procurement Phase:

With the induction of e-buses in the fleet, the optimization of the bus service becomes a critical aspect of the operations, for which both technical and financial parameters need to be considered. Technical parameters include route characteristics such as the daily ridership, the number of buses deployed, frequency of the service etc. In addition, the availability of charging options plays a big role in deploying electric buses. Both overnight and opportunity charging needs to be considered so that the electric bus can meet the duty cycle requirements. Financial parameters include TCO analysis of the route. TCO takes into consideration both capital and operating cost on a per km basis and helps understand the total cost of the bus over the life of the bus taking into consideration efficiency, battery replacement, running kms annually etc. The rest of this section discusses the optimization of the operations and optimization of charging for the continuous monitoring and evaluation of the e-buses, which help to improve the efficiency of the overall operations.

5.2.1. Internal Scheduling and Monitoring

Monitoring:

Continuous monitoring and evaluation of the transit authority's performance is a necessary step towards optimisation - the best possible use of the available resources. The transit authority should define and develop Key Performance Indicators (KPIs) and start collecting relevant data, and then analyse the data to derive key conclusions. Such a data-driven approach is necessary for transit authorities due to limited financial resources.

Data analysis provides insight into how the buses are performing in a service area and if they are being fully utilized. The results can inform operational changes that will allow getting the most out of the electric buses, helps understand the true costs and benefits of the deployment, and inform future needs of an electric bus fleet. Best practices for data monitoring and evaluation include:

- Defining key performance indicators and metrics for reporting.

- Identifying and coordinating internal and external sources for operations and maintenance data.
- Ensuring bus performance data is developed for fair and accurate reporting of metrics, especially when compared to diesel buses and vehicles of different ages.

In addition, data monitoring tracking and reporting lead to early identification and mitigation of deployment issues. Common Key Performance Indicators for electric bus deployments are:

- **Energy cost per km**- It is essential to track energy costs per km to determine if bus operations are in line with a STU's/Operator's estimate. Since transit agencies typically track fuel costs per mile, this is the easiest metric for comparing electric and diesel buses. For electric buses, cost per km also allows transit agencies to see the impact other factors (e.g., weather, topography) have on deployment costs.
- **Energy performance** - The energy performance and energy efficiency of the electric bus fleet will inform range, identify any seasonal variability, and identify energy efficiency trends by route or operator. Cross-referencing energy efficiency with temperature or auxiliary usage will allow to see how temperature and related HVAC loads impact efficiency.

  Energy consumption (kWh) provided by OEMs or third parties does not typically account for any grid-to-charger or charger-to-bus loss. While this data is useful in understanding the efficiency of the bus, it does not equate to the actual kWh consumption that would be charged to the utility bill. Additionally, buses may have standby energy consumption that is not reported as energy used while driving.
- **Availability and utilization of the electric bus fleet**- Availability will indicate how often the electric bus was put into service. It is important to measure the in-service (road calls should also be tracked on days when the bus is put into service). It also records when the buses were recalled or were removed from the service due to any incident. Utilization measures the actual usage of the electric bus compared to the possible usage. It can be measured by comparing the number of days a bus was actually put into service to the total days it was available to be put into service. Low utilization could indicate that there are operational issues. Tracking utilization can help transit agencies identify the root cause of issues and address them.

- **Emissions reductions due to deployment of electric buses** - Common GHGs associated with diesel combustion include carbon dioxide (CO_2), carbon monoxide (CO), nitrous oxides (NO_x), volatile organic compounds (VOCs), and particulate matter (PM). The fuel economy for conventionally fueled buses should be used to estimate gallons of diesel avoided from electric bus operation. In addition to calculating GHG emission reductions, more and more cities are calculating a net health benefit as well, since those same reductions also reduce the incident of health problems from particulate matter (PM) in those emissions.
- **Ongoing lifetime cost analysis** - Comparing the actual operating and maintenance costs to the projected costs throughout the service life of the fleet would be an important aspect in monitoring. Utilizing similar data for diesel/CNG can help in comparing the vehicle technologies as well. Few bus operators in Shenzhen have leased vehicles from manufacturers. This greatly saved operators' upfront investments and reduced the need for debt financing. In Shenzhen, bus manufacturers provide a lifetime warranty for vehicles and batteries instead of bus operators and this has helped in reducing the lifetime cost due to better operating and maintenance practices. According to a study conducted by the World Bank[40] , without purchase subsidy, the present value of the lifetime total cost of an electric bus would be 21% higher than a diesel bus. With government subsidy, the total cost of the electric bus would be 35% less than that of a diesel bus.
- For maintenance costs, all maintenance activities and mid-life rebuild/replacement activities should be included. It is important to create a method for tracking any activity during the warranty period as well. While service during that period may be covered by the OEM, it is important to understand what maintenance activity has been required. This information can help inform expectations going forward. Reports need to ensure fair comparisons between different vehicle technologies and different vehicle ages; care should be taken to ensure that the cost and performance data are comparable.

[40] *https://openknowledge.worldbank.org/handle/10986/35935?show=full*

Data from several, disparate sources need to be collected to support robust data reporting.

- **Electricity Bills**: The total costs from the electricity bills can be used to calculate the energy cost per km. Comparing the total kWh billed to the energy consumption data from other estimations or data sources (i.e., OEM or third-party data monitoring systems) can help understand efficiency loss between the grid, the charger, and the bus.
- **OEM platforms** – Some OEMs provide a data monitoring platform to track performance data. Most platforms allow to view detailed energy consumption data, and track the state of charge, mileage, charging, and other metrics. Coordinating with the OEM to understand the available options for accessing data monitoring portals or performance summaries should be negotiated during the contracting procedure. It is important to have a clear understanding of what is being reported and how it is being calculated/provided.
- **Third-party platforms** – Third-party solutions can provide real-time data on electric buses. These services will work across OEMs to allow monitoring of the technologies. Oftentimes, these services create customizable reports, providing the data at the desired frequency.
- **Asset Management Systems and Maintenance Reporting Systems** – The maintenance department will have information on vehicle service needs, parts and labor costs, and reasons for a bus being out of service to inform fleet availability and maintenance costs. The operations department typically tracks data such as route driver assignment, driver time on/off, and route time points. Operations may also track reasons for road calls and any driver-reported issues that arise while in service.

Designating a point(s) of contact by the STU to maintain and evaluate the collected data will be the first step in monitoring. That staff will most likely be required to coordinate across departments to collect and validate the data. In addition, application programming interfaces (APIs) should be used to automatically collect data from IT systems, translating the data into a format that can be more easily used. Otherwise, maintaining a spreadsheet is a common approach to maintaining and analysing data. Developing monthly or quarterly reports for review is recommended. The tables below list the data that can be collected for further analysis by an STU.

Table 6: Route-specific Data Collection

Parameters	Unit
AC/Non-AC	-
Route Name	-
Route Characteristics	
Average Travel Speed	km/h
Route length (tour-retour)	km
Average time (tour-retour)	min
Number of stops (tour-retour)	-
Average distance between stops	km

Table 7: Data Collection for Batteries

Parameters
Battery Identification Number & VIN
Calendar life of the battery
Battery Voltage during charge/discharge
Battery current during charge/discharge
Battery temperature- min, mean and max
Battery capacity
SoC and DTE with time stamp
SoH with cycles
GPS co-ordinates with time stamp
Vehicle speed
Odometer values
Battery maintenance logs
CAN data configuration is needed to understand CAN data

Source - Gaadiwaadi.com

06

Procurement & Financing of e-Buses

6.1. Introduction

Procurement and financing are interdependent aspects of acquiring any asset including those meant for public transportation. The possible methods of procurement include outright purchase, right to use (lease), operating contracts, public-private partnerships etc. In the case of e-buses, the method of procurement requires consideration of many aspects including technical competence, infrastructure requirements, operational planning, ability to raise capital and cost of funding, organizational preference etc. It is seen that certain public transport agencies traditionally prefer outright purchase of buses with in-house operations while certain others primarily outsource this function.

Under the FAME-1[41] scheme of capital subsidy for E-buses, transport agencies had the choice of choosing either model, however, in the FAME-II scheme, the subsidy is only available only for gross cost contracts.

It is seen that cities with prior experience of out-sourced operations (e.g. Ahmedabad) were able to procure e-bus contracts easily with competitive rates whereas cities such as Bengaluru have struggled to close their tenders and have needed additional subsidies from the State Government to bring down the GCC rates to acceptable levels. Although various cities essentially procured essentially the same service around the same time, the terms of the contracts varied significantly resulting in significant differences in procurement outcomes (Refer to Figure 42).

[41] *Faster Adoption and Manufacturing of Electric Mobility: Phase I-2015-18, Phase II– 2019-22*

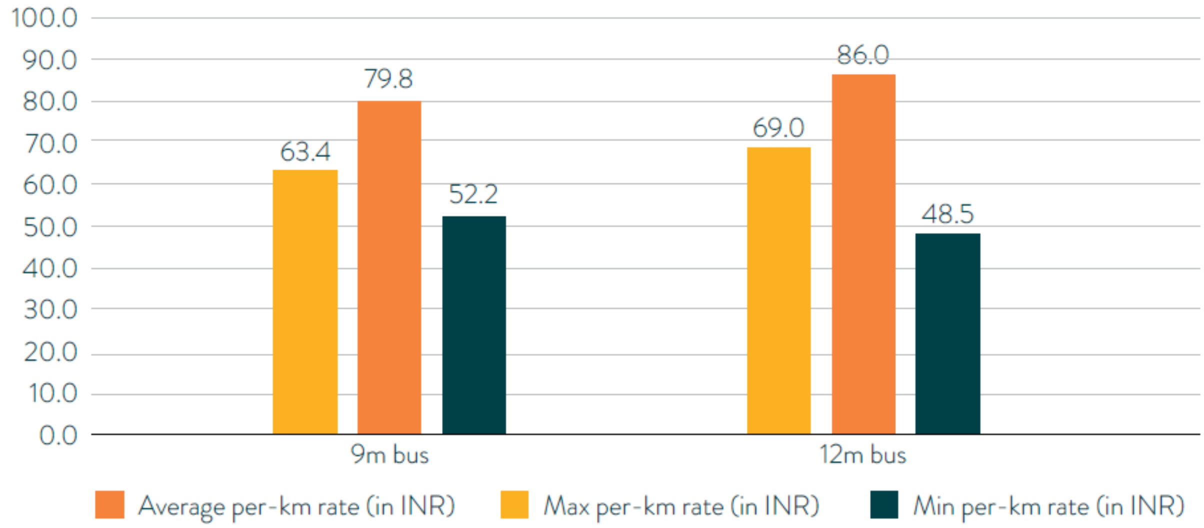

Figure 42: Range of L1 bids for 9m and 12m under FAME-II Scheme[42]

Thus, procurement and financing of E-buses is a strategic choice but also has bearing on the cost of procurement. The various traditional, as well as evolving options for procurement of E-Buses, are discussed in the following paragraphs.

6.2. Contracting Policy

6.2.1. Bus Operation Contract Models

The implementation of urban transport services can be divided into four broad categories:

i. **Owner-Operator Model:**

The Transport Authority owns its own fleet and provides the services departmentally through its own employees. Capital and policy support is provided by the municipal/ provincial/ national government(s).

[42] *Electric bus procurement under FAME-II: Lessons learnt and recommendations for Phase-II, UITP, Shakti Foundation, July 2020*

This model is used where bus services are newly introduced, the scale of operations is low, suitable private operators are not available or where the employee unions are strong and resist private operators' entry. Several cities in India including Mumbai, Kochi and Bengaluru have operated under this model.

ii. Management Contracting Model:

The investment in the transportation assets is primarily made by the Transport Authority and an operator is appointed to provide the services using the assets and within predefined quality and service parameters. For example, in Cape Town, South Africa, MyCity Integrated Rapid Transit procured and provided the 12 m buses to the operators for a 12-year contract[43]. The common features of this model are:

- Buses to be procured and provided by the Authority.
- Fare Collection responsibility is with Authority
- Payment on per km operated basis with guaranteed kms per year
- For under/excess utilization, the partial fee is paid
- Fees revised in line with an increase in fuel prices/inflation,

However, in order to incentivize the operator to take proper care of the Authority's Assets, several Indian cities have tried different approaches as shown in Table 8.

Table 8: Some examples of Management Contracting from India

City	Variation	Benefits
Indore (2013-18)	At the end of the contract period, buses to be auctioned and sale proceeds are divided between the Authority and operator in the ratio of 60:40.	• Incentivizes the operator to keep the buses in good condition • Reduces per kilometer rate
Ahmedabad (7+1 years)	Ownership of buses transferred to the operator at book value at the end of the contract.	• This reduces the per kilometer rate. • Incentivizes the operator to keep the buses in good condition

[43] MyCity Business Plan 2012 - https://www.myciti.org.za/docs/categories/1606/Complete_MyCiTi_Business_Plan_2012.pdf

Amritsar (2013-19)	Fuel to be provided by the Authority at fixed mileage of 3 km per liter	● The operator is incentivized to upkeep buses in sound condition and cultivate good driving habits in order to maintain required mileage.
Surat (2008-2015 and renewed)	Joint Investment: Bus chassis procured by Authority, bus body by Operator. Ownership of Buses would be transferred to Operator at the end of contract period	● Reduces investment burden on the Authority ● Incentivizes the operator to keep the buses in good condition.

The management contracting model can be used where the transit authority already owns the buses and wishes to privatise the operations or the private operators do not have the capability or willingness to acquire and finance the buses.

iii. Franchising /Licencing Model:

The identified route/services are assigned to operators who apply for it on payment of a predefined license fee by the Licensee or a subsidy/grant amount payable by the Authority to the Licensee in case of loss-making but socially desirable services. This model is suitable where the ridership patterns are well established and the transit authority wants to minimize its involvement in the operations. The Mira Bhayander Municipal corporation operated this model from 2005 to 2017 and since then it has moved to gross cost contracting.

iv. Buy the Service Model:

Private operators are appointed who acquire the buses. Depot land/infrastructure may be provided by the transit authority on an "as is" basis or the operator may need to arrange it (e.g. London/Jakarta). There are two main variations in this model based on the mode of remuneration to the operator, namely:

a) *Gross Cost Contracting* (GCC) – The Authority frames rules, policies, routes, fare structure and other service parameters and procures the transportation services from private operators. Authority collects the fares and bears ridership risk and the operator is paid on the basis of fleet size and/or kilometres run.

b) *Net Cost Contracting* (NCC) – Similar to GCC except Operator collects and appropriates the fare and consequently bears the ridership risk and often the risk of delay in fare revisions. Depending on the profitability of the operations, either the operator pays a premium or receives a fixed subsidy based on kilometres run from the Authority.

A comparison of the GCC and NCC models of operations is presented in Table 9.

Table 9: Pros and Cons of GCC and NCC[44]

	Gross Cost Contracting	Net Cost Contracting
Pros	• Flexible operation • Easy to introduce • Reduces on-street competition and unscheduled stops • Ensures service levels during lean hours • Lower risk to operators results in efficient pricing • Quality of service is part of performance parameters	• Transfers revenue risk to the operator • Allows public agencies with limited staff and technical capacity to manage the operations • Reduces the risk of fare evasion leading to subsidies
Cons	• Authority bears all the revenue risk. • Needs a strong Authority and very good supervision • increases the risk of operators skipping passengers, fare evasion and need for subsidies • increases the risk of driving more kilometers than needed • Applicability of goods and services tax on fee payments	• Lack of flexibility. Difficult to add more services • Overlapping routes compete for passengers • Maximizing profits is the priority rather than service quality • Operators wait to fill up the bus and pick up passengers at unregulated stops
Suitability	• Markets where accurate revenue forecasting is difficult and creditable track record is not available such as the introduction of new services/routes	• For established markets where the ridership level have stabilized and fare revisions are predictable

[44] *Bus Karo - Guidebook on Planning and Operations, EMBARQ, 2010*

Many net cost contracts in India failed to achieve desired outcomes or even run the course of the contract. The NCCs in Kota, Jalgaon, Jodhpur, Rajkot, Delhi (DMRC Feeder), Vadodara, and Ludhiana for instance, were closed or prematurely terminated, whereas the transit authorities in Ujjain, Indore and Bhopal found it difficult to expand the system. Often cities move to GCC after failing to receive adequate interest for NCC tenders (Ludhiana, Amritsar etc.). On the other hand, GCC contracts once awarded are found to be easy to operate. Many cities including London, Delhi, Indore, Bogota, and Ahmedabad have successfully operated on a GCC basis for a number of years[45].

Given the relative merits and demerits of GCC and NCC, a mixed approach creates an environment for equitable sharing of risks and incentives between the authority and operator and thus gives optimal results i.e. profitability balanced with service. Some city bus systems have utilised a mixed approach in order to minimize these negative outcomes inherent in gross and net cost contracts. For example, in Transmilenio, Bogota, the operator is paid based on both kilometers run and fare revenue collected. Some features of the model are as follows:

- A fixed percentage of the total revenue is shared amongst the 7 trunks, 6 feeder and 2 fare collection concessions incentivising the operators to provide maximum service.
- There is no fixed rate per kilometre and total revenue is distributed amongst the operators based on kilometres run (see Figure 43).
- Operators must maintain a specified load factor and hence the operator minimises empty/low ridership kilometres.
- Penalties and bonuses applicable based on service quality,. e.g. Penalty is applicable, inter alia if dispatch compliance is less than 95% or regularity index is less than 70%.

Similarly, incentives are paid when the Operator Total Performance Index (weighted average of Regularity (20%), Punctuality (15%) and User Satisfaction (65%) indices) is above 80%. The money available from the penalties is distributed among the operators that are eligible for a bonus in proportion to their final quality score.

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[45] Prof. H. M. Shivanand Swamy and Gautam Patel, PPP Arrangements in Urban Transport, 2nd Asia BRT Conference, Ahmedabad, September 2014

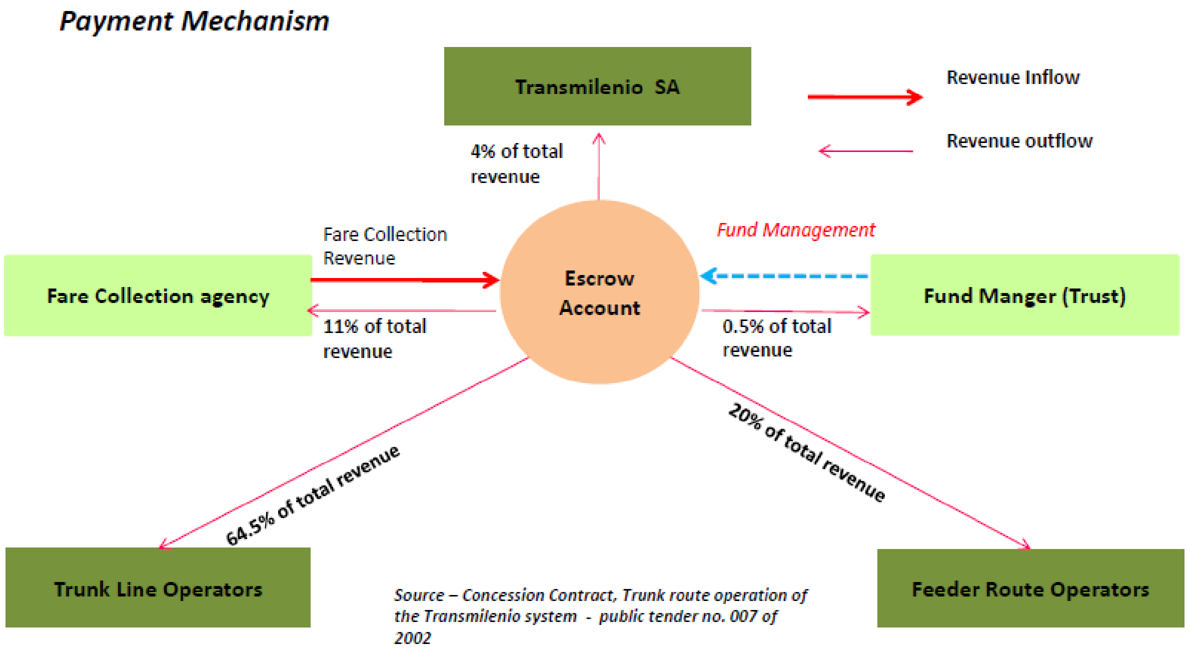

Figure 43: Distribution of Fare Revenue for the TransMilenio Bus Service System[46]

While improving upon several deficiencies of the GCC and NCC, the mixed approach also suffers from two main deficiencies:

- The payment system is complex and not straightforward for the operators
- Operators do not have the incentive to increase the number of buses resulting in overcrowding in peak hours.

6.2.2. Contract Duration

The length of the contract duration depends on the following main factors:

- **Flexibility to change policies/clauses** – Longer duration hinders the ability of the authority to align the services with the needs of the users and bring in changes such as less-polluting vehicles, route rationalisation etc.

[46] *PPP ARRANGEMENTS IN URBAN TRANS, Prof, Shivanand Swamy and Gautam Patel, 2nd Asia BRT Conference, Ahmedabad, 2014*

- **Useful life of the assets** – Shorter concession periods result in partial utilisation of the assets and a higher CapEx charge per kilometre. On the other hand, if the concession period is too long, the overuse of the assets beyond economic life may result in higher operations and maintenance (O&M) costs or lower quality of service (user comfort, reliability, safety etc.). The concession duration is often determined based on the useful economic kilometrage of the buses as shown in Table 10.

Table 10: Useful economic life of buses

City	Type of Bus	Lifetime (km)
Megabús of Pereira	Diesel	800,000
Transmilenio, Bogota	Articulated Bus	1,000,000
	Electric	15 years
Transantiago, Chile	Diesel	1,000,000
	Hybrid	1,800,000
	Electric	14 years

- **Investment needed to be made by the operator** In case, the operator is required to invest in transit infrastructure, the contract period may be longer.
- **Asset Specificity** – If the assets acquired can be used elsewhere without much significant cost, the concession period may be short e.g., diesel buses after their prime use can be used for school or corporate staff transfer.

  In the case of articulated buses or E-Buses designed for a particular route, it may be difficult or uneconomical to use them elsewhere.

The best practices on public transport concessions recommend a contract period between 7 and 12 years. Table 11 shows the contract durations adopted by some of the cities:

Table 11: Concession Period of different city bus systems

City	Operation contracts period
León (Mexico)	15 years
Mexico City (Mexico)	10 years
Uberlandia (Brazil)	10 years
Stockholm (Sweden)	8-10 years
London (UK)	5 years
Bogota (Colombia)	24 years*

**operators had to provide depots and cover the costs of the overhaul of the old units.*

The E-Buses have fewer moving parts and are therefore commonly expected to last longer. On the other hand, their capital cost is very high which necessitates a longer period for recovery. Another factor to be borne in mind is the replacement of batteries generally considered around the 7th year of the operations.

The battery is the most expensive component of the e-bus costing up to 30-40% of the initial capital expenditure. Hence, the duration of the contract has a bearing on whether or not the battery is replaced and if so, how life much of the second battery remains unutilized at the end of the contract. In view of the above, transport authorities are preferring longer concession periods for E-Buses. For example, in Santiago, Chile, the new contracts for 2000 e-buses are likely to have a contract period of 14 years whereas Bogota has leased E-buses for a 15 years period.

6.2.3. Basis of Remuneration

In the case of net cost contracts, route permits/licenses, the operator is compensated for its services mainly from the passenger fare. Depending on the profitability of the route, the operator may pay to or receive additional amounts from the Transit Authority. The possible compensation structure for the gross cost contracts is shown in Table 12.

Table 12: Traditional Gross Cost Contracts Payment Structure

Compensation Type	Pros	Cons
Fixed price (₹/day)	• Simple to manage • Same pay for each route	• No incentive to operate longer schedules • No savings for shorter schedules
Rs. per passenger-km	• Information on ridership/ occupancy levels can be used for better planning of services	• Advanced fair collection methods to be used such as e-ticketing • Operator may not trust the system • More work for the Operator
Rs. per vehicle-km	• Pay in proportion to work	• Operator incentivised to run more kms irrespective of ridership • Operations during peak-hours less profitable for operators
Rs. per vehicle-hour	• Pay in proportion to work	• Operator incentivised to run more trips irrespective of ridership
Rs. per passenger	• Pay based on usage	• On-street competition for passengers • No service level during lean hours

Each of the above structures suffer from some drawbacks and cannot be universally applied. Hence, bus transport authorities also use mixed methods in order to overcome the limitations of each method. For example, the payment to the Vehicle Operators in the MyCity Integrated Rapid Transit, Cape Town, has the following payment structure:

(a) fixed costs
(b) costs related to the number of buses
(c) costs related to the number of drivers, as per the City's scheduling programme and
(d) costs related to the number of kilometres scheduled per vehicle type.

The 12 m buses were provided by the City but the operator procured (and replaced once) the 6 m buses for feeder service during the 12-year contract.

Similarly, Transport for London uses a quality incentive contract structure where the payments to the operators are based on mileage operated and adjusted (increased/decreased) for quality-of-service parameters such as driving quality, passenger service, presentation of the vehicle, punctuality, vehicle maintenance etc.

For electric vehicles, the fixed costs far outweigh the variable costs and therefore a predominantly variable remuneration system will be unsuitable as in case the vehicles are operated for less kilometers than envisaged, the operator won't be able to recover all the fixed costs and the authority will have no incentive to utilize more than the minimum agreed volume owing to higher per kilometer rates as compared to diesel buses. Drawing a parallel from the renewable energy industry where the renewable energy projects, even if having higher tariffs than fossil fuel plants, are granted a must-run status owing to little or no variable costs and environment-friendly nature, the remuneration structure for e-buses needs to be structured in a way that the running of e-buses is preferred over the diesel buses.

6.3. Financing Options for E-bus and charging infrastructure

The financing options for any project implicitly depend on the contracting structure.

Table 13: Sources of Finance for different Business Models

Business Model	Sources of Finance
Owner-Operator/Management Contracting	Grants/subsidy, equity, commercial loans, foreign currency loans, internal accruals
Capital Lease /Operating Lease	Leasing Company
Gross Cost Contract/Net Cost Contract/ Licenses/Route Permits	Bus Operator (loan/equity/lease)

Considering the significantly higher acquisition cost, additional infrastructure costs as well as lack of understanding of the operation and maintenance challenges of the e-buses, most authorities prefer financing of the e-buses through concessions.

Due to the same reasons, e-buses are not suitable for net cost contracting concessions. Therefore, the most preferred option is gross cost contracting. However, most bus operating companies find it difficult to raise the capital for procuring the e-buses and the associated charging infrastructure due to one or more of the following reasons:

1. Most bus operating companies are unorganised or unincorporated
2. Lack of profitable track record
3. Low net-worth and promoter credentials
4. Poor credentials of government counter-party/transit authority, concerns over delayed payments, non-revision of fees, arbitrary cancellations and/changes in terms of contracts etc.
5. Lack of credit rating
6. The uncertain collateral value of the E-buses and little/no collateral value of infrastructure assets
7. Longer tenure required to pay the loans

Even if the lenders agree to fund the e-buses, the equity funding requirement from the operator increases many-fold as shown in the example below:

Table 14: Net Operator Funding Requirement for E-buses

Parameter	Diesel Bus	E-Bus	Remarks
Acquisition Cost	₹60,00,000 ($77k)	₹1,80,00,000 ($231k)	Including infrastructure costs
Method of Financing	Asset based	Project Finance (Contract based)	
D/E Ratio	80:20	60:40	Assumption
Debt Amount	₹48,00,000 ($62k)	₹1,08,00,000 ($138k)	
Equity Amount	₹12,00,000 ($15k)	₹72,00,000 ($92k)	

Considering the increased funding requirement, there is more reluctance to adopt the new, expensive and evolving technology. Different strategies have therefore been adopted for promoting and accelerating the adoption of e-buses in the transport systems. These can be broadly categorised as follows:

a. Traditional Financing
b. Bus Leasing by manufacturer
c. Battery Leasing
d. Separation of Bus Ownership and Bus Operation
e. Pay as you Save (PAYS)

The above models are described with case studies in the following paragraphs.

6.3.1. Traditional Financing

The diesel buses are funded by transit authorities either using grant funds received from the government and/or internal accruals and loans. Similarly, government grants can be used to fund e-buses e.g., the Federal government of Germany has agreed to fund 80 per cent of the incremental costs of electric buses through grants in addition to providing no-cost lease of land for charging stations to encourage the five biggest cities in Germany to order at least 3,000 electric buses by 2030.

Municipal green bonds can be an effective tool for creditworthy municipal corporations to consider for the financing of e-buses. Municipal/provincial governments can pool the requirements for funding the e-buses for the transit authorities/companies and issue 8–10-year bonds. The incremental cost of debt service as compared to acquiring and running diesel buses will be less than the savings from lower energy and maintenance costs. In case a common procurement procedure can be followed, there may be additional benefits of reduction in prices and procurement costs. In some countries, the municipal green bonds may even enjoy tax benefits or be attractive investments for “green funds” thus reducing the costs further.

Multilateral and bilateral overseas development financing agencies such as the World Bank, Asian Development Bank, KfW, Asian Infrastructure Investment Bank etc. provide financial assistance for public transport projects, especially for low carbon mobility solutions.

The ₹5890 crore ($755 million) loan from KfW to the Government of Tamil Nadu to fund 80 per cent of the acquisition cost of 12,000 Euro VI diesel buses and 2,000 battery-electric buses is an example of this[47]. The process and conditions for availing such funding from bilateral agencies are summarized in Annexure-1. Similarly, the Asian Development Bank (ADB) approved a $50.65 million (₹395 crore) package to help the Kyrgyz Republic procure battery-electric buses and enhance transport infrastructure in the country's capital city Bishkek. In December 2019, the ADB had proposed a loan of $300 million (₹2300 crore) to Bank of Communications Financial Leasing Co. Ltd., China for funding the New Energy Bus Leasing Project.

The private operators generally procure the buses using a debt and equity mix. The debt is typically provided using the bus as the collateral making sure the residual value at any point of time is more than the outstanding debt.

6.3.2. Bus Leasing by Manufacturers

The biggest bottleneck for induction of e-buses into the fleets of operators is the high investment requirement and uncertainty with regard to its operations and battery life/replacement costs, and technological obsolescence. All these issues can be resolved in cases the buses were made available on an operating lease or a capital lease with maintenance and service support from the manufacturers. It helps the operator to achieve the advantage of the lower lifetime TCO of e-buses from day one and provides time to develop bus operator's confidence in the technology.

For example, Proterra, USA offers, inter alia, the following financing options for its customers:

- Municipal Capital Lease - A low-cost financing tool for municipalities and local governments with investment grade to raise finance and lease the vehicles.
- Operating Lease: The bus owner may take the vehicle on an operating lease contract with the company for a long period and pay the cost to lower the ICE vehicles of operational costs.

[47] TN govt signs project agreement with KfW to procure new buses | Business Standard News, September 27, 2019

However, good financial ratings or a backing from the government will be needed for manufacturers to extend these facilities to municipalities or transport authorities. However, the manufacturers on the other hand will need financing for funding the manufacturing cost of the buses since the value of the bus is realised over the period of the lease contract eg., the Green Climate Fund announced a USD 1 billion facility to Mytrah Mobility solutions to manufacture 5,000 E-buses. The term of the loan was for a period of 15 years and provided through the Small Industries Development Bank of India[48].

6.3.3. Battery Leasing

The average cost of an electric bus is 2-3 times of a diesel bus, forcing transit operators to rely on government subsidies to bring the cost down. One alternative strategy can be to leasing the battery, the most expensive component of the E-bus. Since the operating cost of e-buses is much lower than the comparable diesel or CNG buses, the higher lease charges can be accommodated due to the savings in operating costs.

Proterra, USA in partnership with Mitsui (financial institution) provides option to operator to purchase the bus chassis, and lease the battery and charging infrastructure from the manufacturer. Proterra is responsible for the performance of the batteries through the life of the lease, removing operator risk. The model was used in Park City, Utah, where it increased the number of buses that could be purchased with the allocated funds and paid for the batteries from the operational savings.

Similarly, in Virginia, Dominion Energy is bringing 50 electric school buses to 16 localities in the utility's service area in phase 1. Using a Dual-Ownership model, Dominion offsets the additional capital costs of electric buses and charging infrastructure and, in return, using Vehicle-to-Grid (V2G) technology, it can leverage the batteries as distributed resources to balance intermittent solar and wind energy generation.

[48] "Mytrah Mobility bags $1 billion from UN-backed GCF for electric buses"; Business Standard, January 22, 2019

When the buses are not being used for transport, the batteries can store energy generated by renewables and discharge that electricity back onto the grid during times of high demand and low renewable generation.

In São Paulo, BYD, China sold 15 buses without batteries to TransWolf, the operator at the same cost as that of a diesel bus and leased the battery and charging infrastructure for a monthly fee payable over 10 years. In addition, BYD is also providing the charging services by investing in solar photovoltaic plant.

6.3.4. *Separation of Bus Ownership and Bus Operation*

This solution focuses on transferring ownership of E-bus assets-charging infrastructure, bus and batteries to new players who have capital available to make the investments. Operators would then lease E-bus /components from these asset owners. This mitigates the risks for operators and distributes risk across actors, as demonstrated by current model in Santiago with Engie, Enel and private operators. The different examples of implementation of such financing mechanism are discussed here.

Dual Concession Model, Bogota

In order to overcome the challenge of motivating the operators to invest in sustainable technology and avoid the increase of tariffs to the end-users, Transmilenio, Bogota has launched a new concession scheme that separates the acquisition and supply of the electric buses (first concession) from their operation and maintenance (second concession).

The terms of the first and second concessions are 15 years and 10 years respectively. This mechanism reduces the financial risk to the investor and the technological risk to the operator. Enel-Codensa, the utility company, will be responsible for design, construction and provisioning of the charging system. Under this scheme, Celsia, an Argos Group energy company, has purchased 470 electric buses from BYD, China and leased them to Transmilenio for 15 years.

6.3.5. *Pay As You Save® (PAYS®[49]) Model*

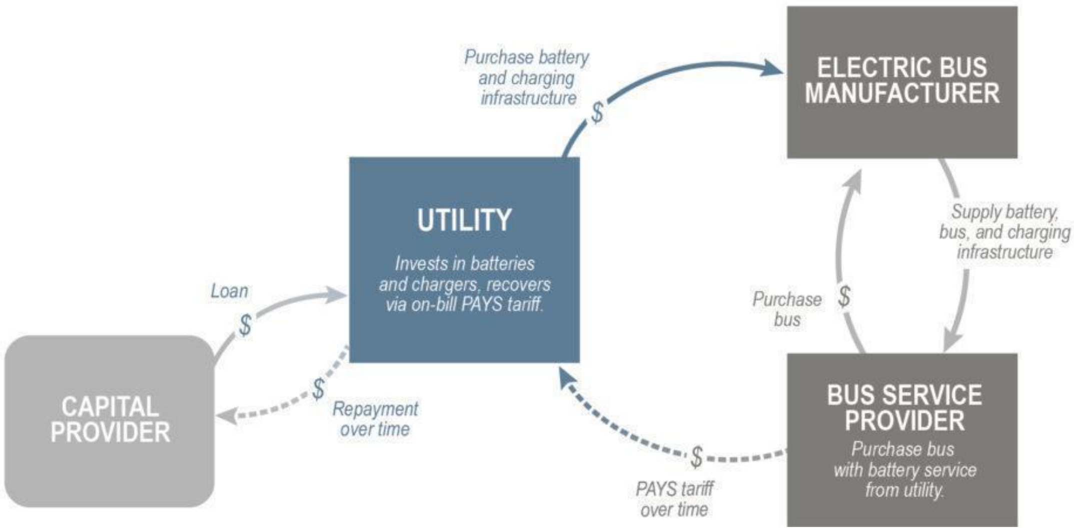

Figure 44: Schematic showing the PAYS Model

PAYS model helps in overcoming barriers to investment without imposing additional liabilities on customers (unlike loans or leases). The PAYS model for Clean Transport, endorsed by the Global Innovation Lab for Climate Finance works is graphically represented in Figure 44. The mechanics of the PAYS model is as follows:

- A utility invests in batteries and charging infrastructure for e-buses thereby reducing the upfront cost of the e-bus. The utility leverages its access to capital to expand its revenue base as it assures the business of supplying electricity for charging the E-Bus.
- The utility then provides charging service to the bus operator. The PAYS tariff allows the utility to recover its costs within the warranty period through a fixed charge on the bus service provider's regular monthly electric bill. The tariff is calibrated to ensure the estimated operating cost of an electric bus is less than that of a comparable diesel bus. This approach enables bus service providers to pay for the costs of the batteries and charging stations over time rather than all upfront.

[49] Pay As You Save® and PAYS® are registered trademarks in the U.S. held by Energy Efficiency Institute, Inc.

- Without the cost of the battery and charging infrastructure, the cost of the e-bus is almost same as the diesel bus while the charging fee is less than cost of diesel saved. Thus, the bus operator saves from day one without incurring additional balance sheet liabilities.
- Once the utility's costs are fully recovered, the bus service provider owns the battery and charging assets. In some cases, the battery and charger cannot be fully capitalized within these constraints, so the remaining amount needed to bring the upfront costs of electric and diesel buses to parity is met with grant support; or concessional capital is used to reduce financing costs.

In many cities, an electric bus purchased with PAYS is cheaper than diesel over its life, leverages much greater private investment per grant dollar, and dramatically reduces fleet greenhouse gas and urban pollutant emissions[50]. In Chile and Shenzhen, the implementation is broadly in lines with the PAYS model but with some additional innovations and is briefly described in the following sections.

Procurement e-buses in Santiago, Chile

In 2017, two energy utility companies Enel X and Engie implemented a bus financing structure very similar to the PAYS model but in addition to financing the battery and charging infrastructure, the utilities also financed the buses. However, in return, they got payment guarantees from the city transit authority, DMTT. The financial administrator, AFT which receives the fare revenue and pays operator's fees is instructed to make the payment of lease charges directly to the utility company deducting the amounts from the operator fees. Consequently, the investment for 100 buses leveraged more than 70 dollars of investment capital for each grant dollar, while reducing overall grant requirements by 97%, generating US$ 25 million (₹1.95 crore) in electricity sales revenues, and eliminating 62,000 tons of CO2 emissions. The graphical representation of the Enel-Engie model is shown in Figure 45.

[50] *Pay As You Save for Clean Transport - The Global Innovation Lab for Climate Finance (climatefinancelab.org)*

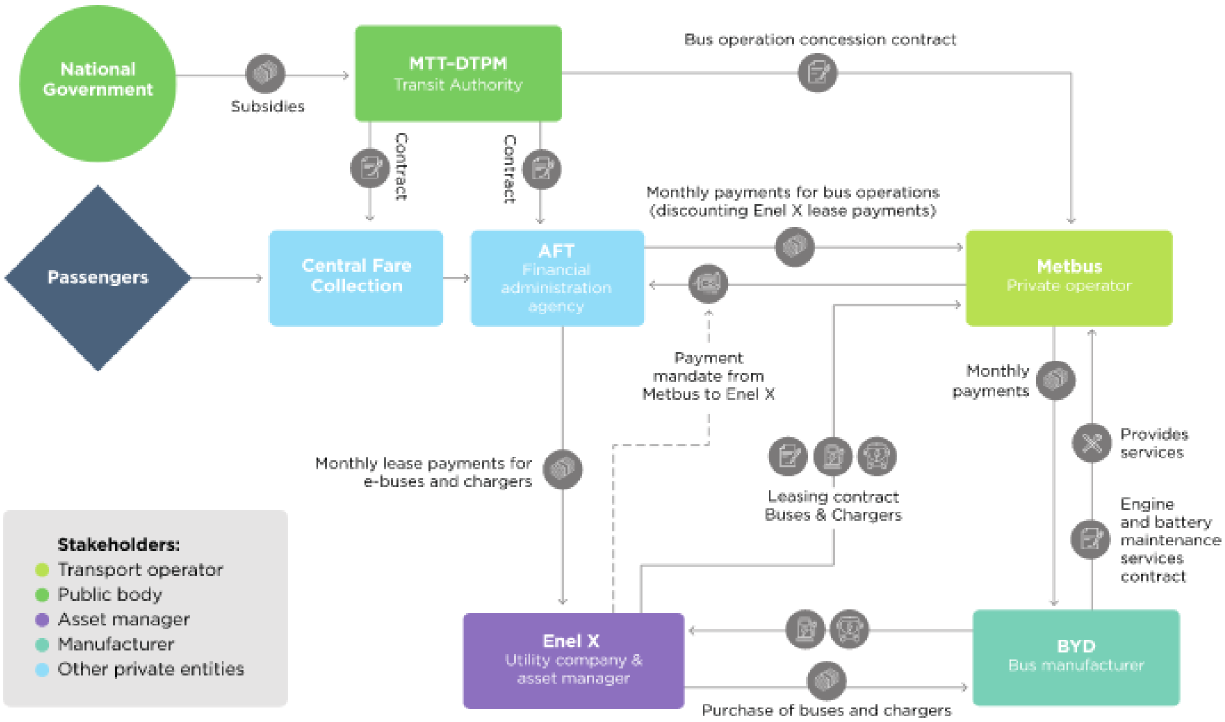

Figure 45: Graphical representation of the Enel-Engie model[51]

Table 15: The Enel-Engie Financing Model

Entity	Deal 1	Deal 2	Responsibility
Utility Company	Enel X	Engie	Buys buses and charging infrastructure from OEM, leases buses to operator, charges the buses and supplies (renewable) energy
Private bus operator(s)	Metbus	Buses Vule, STP	Operate Gross Cost Contract, pay lease rent, energy charges
OEM	BYD	Yutong	E-bus manufacturer, warranty, O&M
City Transit Authority	DTPM[52]	DTPM	Guarantees Payment to Leasing Company

[51] *Zebra Case Study; Metbus Pioneering e-bus deployments in Santiago*

[52] *Directorio de Transporte Publico Metropolitano*

Entity	Deal 1	Deal 2	Responsibility
Financial Administrator	AFT[53]	AFT	Deducts lease fee from operator's fee and remits directly to Enel X
Lease Duration	10 years	10 years	
Number of buses	100	100	

Implementation of PAYS model in Shenzhen

Shenzhen Bus Group Co. Ltd. (SZBG) is the largest e-bus operating company in the world. It has a fleet of over 6,000 e-buses (10.5 m long) and operates a fully electric fleet (excluding a few diesel buses for emergency use). The "Shenzhen model" is characterized as financial leasing, separation of vehicles and battery, and integration of charging and maintenance.

In 2010, SZBG entered into a strategic partnership with Shenzhen Lineng (a wholly owned subsidiary of Potevio, an SOE) by virtue of which Shenzhen Lineng obtained the right to construct and franchise the new energy charging facilities in SZBG. The financing scheme of the various components of the e-bus system was as under:

(1) Separation of vehicles and battery: The vehicle and battery are separately purchased. The battery was purchased by Shenzhen Lineng who received financial subsidies from both the central government and the Shenzhen municipality.

(2) Financial leasing: The bus (without the battery) was purchased by the leasing company and leased to SZBG for 8 years. Shenzhen Lineng provided guarantee to the financial leasing company on behalf of the bus operating company.

(3) Integration of charging and maintaining: Shenzhen Lineng was also responsible for the investment, construction, operation of the charging facilities, and the charging cost, the maintenance costs of batteries and charging facilities. The bus company paid a charging fee in return for the services.

[53] *Adminitrador Financiero de Transantiago*

After deducting the national and provincial subsidies and the cost of the battery, the cost of the e-bus (USD 320,000 or ₹2.5 crore) reduced to USD 104,000 (₹81 lacs), similar to the cost of the diesel buses.

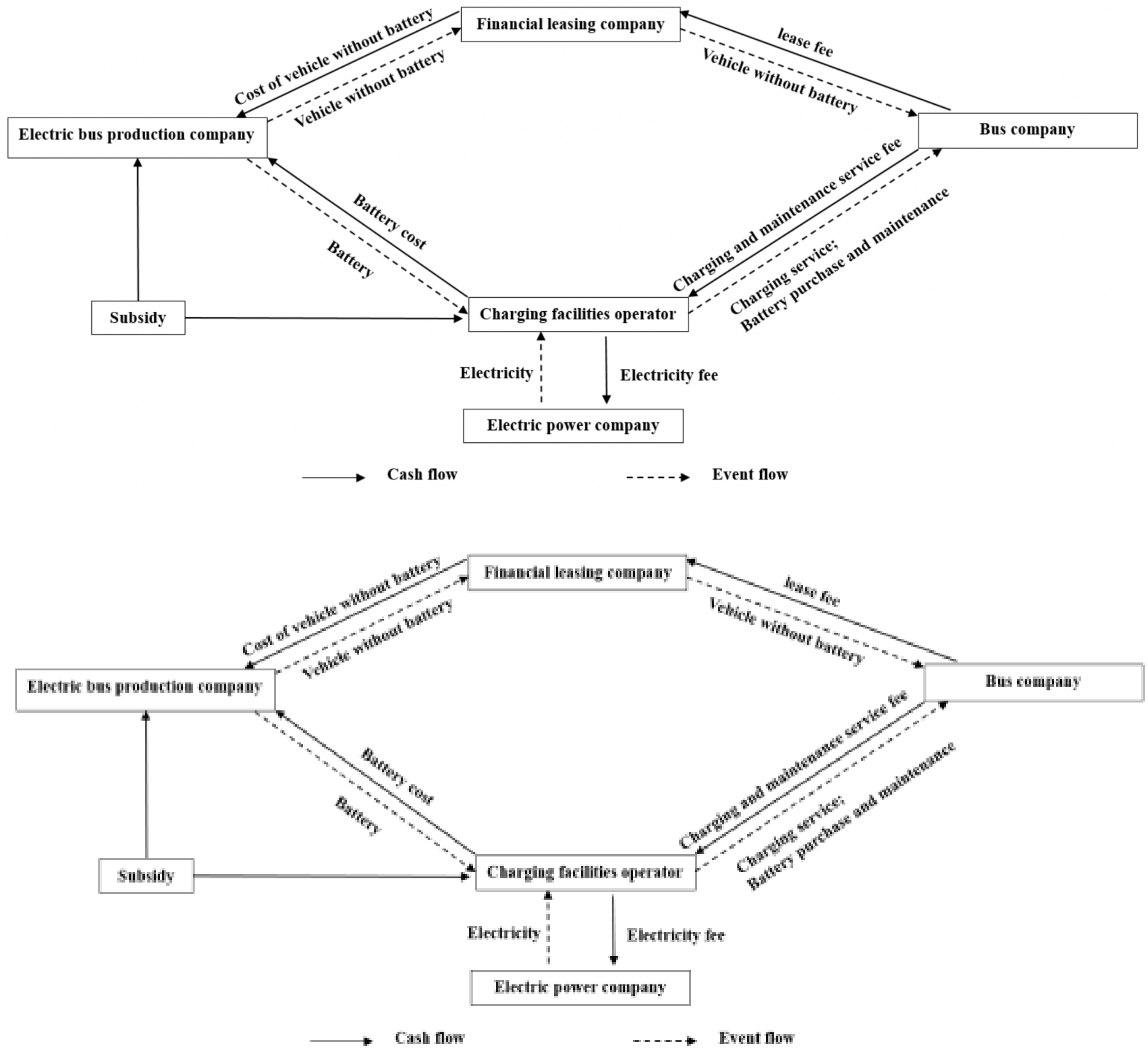

Figure 46: The business model of promoting electric bus in Shenzhen[54]

[54] *Qihang Zhang 2019 IOP Conf. Ser.: Earth Environ. Sci. 295 052048*

Since 2015, SZBG uses a slightly different financing structure as shown in Figure 47. SZBG pays charging service fee to the charging service provider who constructs the charging infrastructure. The Shenzhen municipal government under the "Shenzhen Blue Plan" provided subsidies for charging station construction.

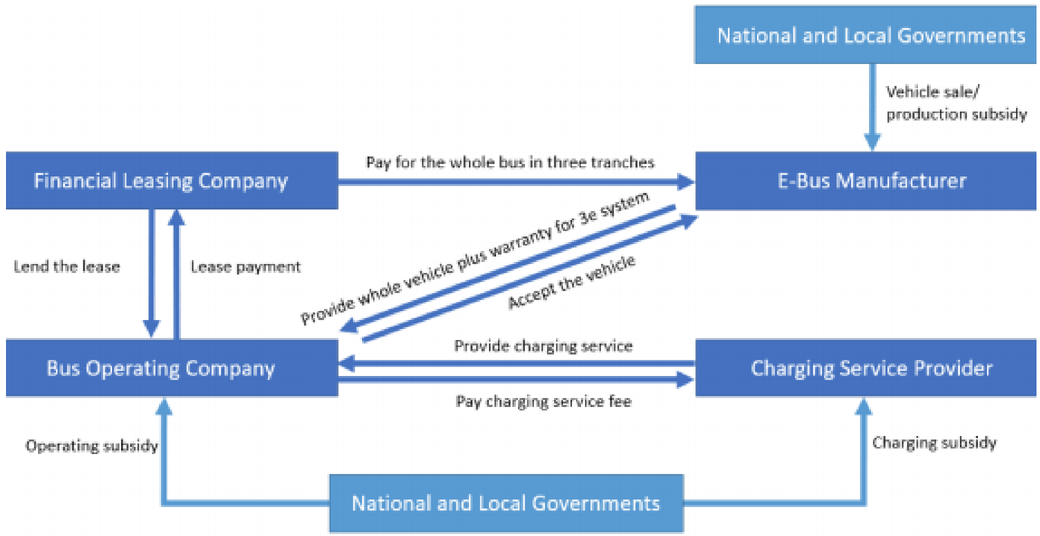

Figure 47: Financial leasing model used in SZBG since 2015[55]

6.4. Project Financing

Given the dependence of the e-bus on the charging strategy, charging infrastructure, operating characteristics of a particular application, there is high asset specificity[56] in e-bus operating contracts. The fact that the e-bus technology is still evolving and prices are coming down consistently, the residual value in alternate deployment is highly uncertain. In other words, in case the operating contract were to be terminated prematurely by whatever reason, the investors are unlikely to realize the full value of the assets in case the e-buses are deployed a few years down the line in any other application.

[55] *"Case Study: Electric buses in Shenzhen, China"; Berlin, A., Zhang, X., Chen, Y. (2020) (with ESMAP support)*

[56] *the degree to which a thing of value, or even a person of value, can be readily adapted for other purposes. A thing with high specificity is useful only for certain tasks or in certain circumstances*

The transit authorities generally require supply of new buses for new contracts, leaving the bus owner to look for plying the buses in school or corporate fleets as the only options.

In view of the above, the bankers are likely to apply the project financing approach to fund the e-bus projects. Where, they do not find the concessions bankable, they may require additional collaterals, credit support or guarantees.

For example, Greencell Mobility (India)[57] is implementing an intercity e-bus project on these lines. The Company secured a contract to operate 48 standard (12 m) e-buses for the Rajasthan State Road Transport Corporation with daily operations ranging between 590-600 kms for a period of 10 years. The total cost of the project of ₹100 crore ($12.8 million) was financed 57% by debt and 43% by equity (debt-equity ratio 4:3).

The sponsors also provided a cost overrun funding support to the banks. To secure the payment of the dues on time, Rajasthan State Road Transport Corporation (RSRTC) will deposit all fare collected from operation of these buses into an escrow account. Further, RSRTC will also deposit 3 months of estimated revenue in advance into the escrow account.

On account of the high usage, effective financing structure and risk mitigation, RSRTC benefitted from an extremely competitive per kilometre rate of less than ₹44.7 ($0.57) per kilometre plus electricity cost. The implementation structure for the project is shown in Figure 48.

[57] *A subsidiary of Green Growth Equity Fund (GGEF) which has been established with anchor investment from Government of India (National Investment and Infrastructure Fund) and Government of UK (Foreign, Commonwealth & Development Office) for investing in sustainability projects.*

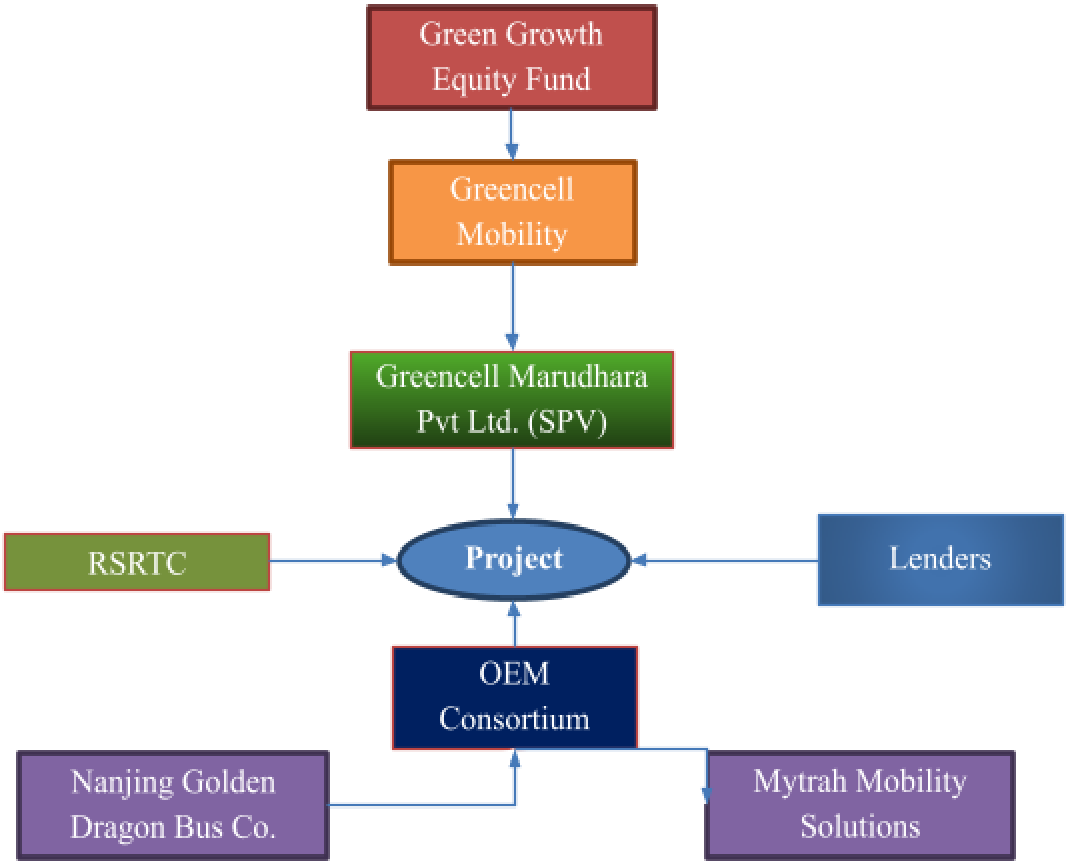

Figure 48: Implementation structure of the project

6.4.1. *Procurement of E-Buses in India under FAME-I and FAME-II Schemes*

The FAME-I scheme was announced in 2015 in which the cities were provided with capital subsidy of up to 60% of the cost of the E-Bus subject to a maximum of ₹85 lacs ($109k) for localization of 15% to 35% and up to ₹1 crore ($128k) for localization of 35% or more. Procurers were allowed to choose between outright purchase and gross cost contract. As can be seen from Table 16, all the out-right procurements were successful although the size of the contract was smaller in comparison to the GCC mode of procurement. In contrast, all but one GCC tender were unsuccessful, and others were either cancelled or retendered with amended terms and conditions. Reportedly, the only successful GCC tender had to be entirely funded by the Manufacturer/ Operator (Olectra Greentech).

Thus, the entire E-Bus fleet procured as part of the FAME-I scheme was funded by the Government or the Bus Manufacturer and no outside funding was secured.

Table 16: Summary of E-bus Procurements Under FAME-I Scheme[58]

City/State	No. of Buses	Status
Gross Cost Contract		
Karnataka	80	Tender cancelled
Mumbai	40	Tender cancelled
Hyderabad	40	Contract awarded, operational now
Ahmedabad	40	Tender cancelled and re-awarded without FAME subsidy
Jaipur	40	Tender cancelled
Out-right purchase		
Indore	40	Awarded. Buses Supplied
Lucknow	40	Awarded. Buses Supplied
Kolkata	40	Awarded. Buses Supplied
Jammu	15	Awarded. Buses Supplied
Guwahati	15	Awarded. Buses Supplied

The implementation of the FAME-II scheme was significantly different than the FAME-I in the following aspects:

1) The scale of the scheme was increased many-fold both in terms of the funding as well as the number of buses
2) The capital subsidy per bus was reduced to 40% of the cost of the buses with a maximum of ₹45 lacs ($58k) for the 9 m buses and ₹55 lacs ($71k) for the 12 m buses and was also linked to the battery capacity of the bus

[58] *Fiscal incentives to scale up adoption of electric buses in Indian cities, UITP, Shakti Foundation, March 2019*

3) It made procurement under GCC mode compulsory and the option for out-right purchase was removed

The scheme also required the transport authorities to finalize the tenders within a limited period of 12 weeks from the issue of letter of intent. This ensured there were a flurry of tenders for gross cost contracts using E-buses in 2019 and 2020. As of December 2021, orders for 6,265 e-buses has been placed by various states/cities under the FAME-II scheme. This is in addition to the 425 buses procured under FAME-I as well as the buses purchased without FAME subsidy.

Further, EESL has launched a joint procurement of 5,585 E-buses for Delhi, Hyderabad, Bengaluru, Surat and Kolkata comprising of 3,472 buses under FAME-II and remaining with state subsidy. This round has seen considerable amount of outside financing in the form of private equity (Greencell Mobility), bank financing (IndusInd Bank, State Bank of India etc.) in addition to the funding by manufacturers and subsidy from Government.

Several procurers were able to finalize their tenders at very competitive prices viz. RSRTC, Ahmedabad and other cities from Gujarat while some had to retender. Bengaluru found it most difficult to finalize the E-bus contracts although it was one of the early starters way back in 2014. It was able to close both its tenders (90 midi buses and 300 standard buses) in 2021 after several rounds of unsuccessful tendering and additional capital subsidy from the state government to bring down the tender prices.

Table 17: List of awarded tenders under FAME-II Scheme

City/ SRTUs	No of e-buses	City/ SRTUs	No of e-buses
Hyderabad	300	Kerala	250
Warangal	25	Indore	100
Other Andhra Pradesh Cities	300	Bhopal	100
Andhra Pradesh SRTC	50	Jabalpur	50
Guwahati	50	Gwalior	40
Silchar	25	Ujjain	50

Jorhat	25	Mumbai	340
Patna	25	Pune	150
Chandigarh	80	Navi Mumbai	100
Raipur	50	Nagpur	100
Silvassa	25	Nashik	50
DTC (Delhi)	300	Solapur	25
DMRC (Delhi)	100	Maharashtra SRTC	150
Kadamba SRTU (Goa)	150	Bhubaneshwar	50
AJL (Ahmedabad)	300	Jaipur	100
Surat	300	Rajasthan SRTC	50
Rajkot	150	Tamil Nadu	525
Vadodara	50	Agartala	50
Gujarat SRTC	50	Lucknow	100
Gurugram	50	Other UP Cities	500
Shimla-Hamirpur	100	Uttarakhand	80
J&K	150	Uttarakhand SRTC	50
BMTC (Bangalore)	300	Kolkata New Town	150
Hubli-Dharwad	50	West Bengal SRTC	50
Karnataka SRTC	50		
Total			**6265**

Source: ITDP India research, as of December 2021

Besides the delays in completing the tendering processes, the tendered prices also varied significantly. This is attributed to the level of competition, contract conditions, operating parameters etc. as summarized below:

1. Contract Period: Varied between 7 years to 12 years
2. Assured kilometers per day: Varied between 140 km to 225 km per day for intra city operations and up to 600 km/day for intercity operations
3. Fleet Size: Varied from 25 buses to 300 buses or more
4. Dead Kilometres: Some contracts paid for the dead kilometers while other didn't
5. Depot Infrastructure: Some authorities provided existing designated depot with requisite electricity connection while others required the operators to arrange their own depot infrastructure
6. Charging Strategy: Some contracts allowed opportunity charging while others didn't

In addition to the above, the experience of the tendering agencies with respect to Gross Cost Contracting, their financial health and profitability etc. varied. This impacted their ability to formulate the tender documents and operating plans. Although the model operating contract drafted by NITI Aayog provides an excellent base document, authorities have modified and/or supplemented the same with additional conditions which have a bearing on the structure of the concession.

Notably, the authorities like to keep certain discretionary powers either because they are not fully prepared for the e-bus adoption and hurrying through the tender process to meet the DHI deadline (e.g. Identification of depots, routes, infrastructure provisions etc.) or they like to have the powers to change contract conditions for operational flexibility without compensating the operator e.g. changing deployment of e-buses from one route to another.

6.4.2 *Joint Procurement*

In order to reduce the acquisition cost of e-buses, often various entities located in the same geographic region pool together their requirements and go through a joint procurement process. In 2017, the Polish Development Fund signed an agreement with 41 local governments for the purchase of 780 electric buses. During the same year in Copenhagen, Denmark, a joint procurement process involved 10 municipalities, 3 regions, the state-owned network company, and the capital's utility to achieve discounts on the total number of EVs purchased. The procedure saves administrative efforts and reduces procurement costs. Also, large sized tenders attract the attention of a greater number of bidders thereby increasing competition and bringing down the costs.

In India, the Government of Uttar Pradesh aggregated the demand for 14 cities and acquired 700 e-buses in 2021 through gross cost contracting and achieved better success than most other cities procuring individually around the same time. Similarly, Convergence Energy Services Ltd (CESL), a Government of India enterprise, has launched in January 2022 the biggest ever tender in the World worth about ₹5,500 crores ($706 millions) to procure 5,585 electric buses including 135 double decker buses aggregated across five major cities in India on gross cost contract. This is the biggest ever demand for electric buses and is likely to result in lower prices due to aggregate demand, high quality benchmarked technology, access to FAME-II incentives, access to state incentives, air quality improvement, and access to domestic and international sources of finances. Standardizing tendering conditions in diverse cities is likely to reduce the effort of the bidders as well as bankers in assessing the request for financing the bids.

Source -sustainable bus

07
Conclusion

The procurement of buses is an extremely expensive affair, it is important to take a systematic approach for the introduction and efficient operations of e-bus in any city. Various activities and learnings in the pre-procurement and post-procurement phases are discussed in the report. Deploying the e-buses without planning could lead to inefficient utilization of the e-buses and other assets, leading to an increased payback period. The report talks about the various aspects of contracting as well as different financial models deployed in different parts of the world for the procurement and financing of buses, followed by the financing of buses in India under both phases of the FAME scheme.

This study also involves a comprehensive review of the electric bus operations in Pune and Pimpri-Chinchwad and a comparison with the internal combustion engine buses. A quick comparison is carried out between the parameters of the e-bus operation for their operation in the cities of Pune & Pimpri-Chinchwad and Hyderabad. The total cost of ownership for the different types of buses operated by BMTC in Bengaluru was also calculated and compared with the corresponding electric buses. A sensitivity analysis for TCO with respect to various operational parameters such as daily operated kilometres, capital subsidy, and bus procurement years is also carried out.

Source - Siasat.com

08

Annexures

8.1. Assumptions for calculation of Total Cost of Ownership for PMPML Buses

	9m electric buses (hired)	12m electric buses (hired)	12m CNG buses (hired)	Diesel/CNG buses (owned)
Air conditioning	Yes	Yes	No	No
Base price per km (as per contract)/ CPK for owned buses	40.32	58.5	62	90.6
Increase in the base price / CPK	1% after every two years	1% after every two years	1% per year starting from the third year	8% annually
Contract period	12 years (10 years + extendable by 2 more years)	12 years (10 years + extendable by 2 more years)	10 years (7 years, extendable by 3 more years)	-
Daily average km operated	225	225	225	225
Fuel cost per km	5.77	6.56	-	-
Personnel cost per km[59]	10	10	10	-
Cost of the bus	50 lakh	50 lakh	0	48.8 lakh[60]
Total cost of ownership calculated over (years)	12	12	10	10

[59] *For Conductors*
[60] *As quoted by vendors for PMPML's tender published in August 2018*

8.2. Assumptions for the TCO Analysis for BMTC Buses

The various assumptions used for the TCO analysis of diesel and electric buses are as follows (In Rupees unless specified otherwise):

Capex Cost/Bus (Rs./Unit in 2021)	E-bus	Equivalent Diesel Bus
Midi Non-AC 125 kWh battery	₹80,00,000	₹25,50,000
Standard (Non-AC) 250 kWh battery	₹1,58,25,000	₹35,50,000
Standard-AC 300 kWh battery	₹1,80,00,000	₹1,11,00,000

Source: Consultant Team based on discussions with vendors/operators

Other Assumptions		Source
Cost of Charger/kW	12,500	Discussions with OEM
Spare Fleet	8.3%	BMTC Administrative Report 2019
Depot Requirement (for 150 buses)	3 acres	BMTC
Cost of Depot Development/acre	₹10crore	BMTC
Cost of electrical connection/depot (for EV Charging)	₹9crore	Discussions with BESCOM
Extra depot space for E-buses	20%	Consultant TeamAssumption

Battery Life	7 years	Discussions with OEM
Repurposing cost of old battery/kWh	$ 49 (2021)	BNEF
Cost of Battery/kWh	$ 250 (2021)	Discussions with OEM
Reduction in battery cost	8.25% p.a.	BNEF (2020)
Discounting Rate	9%	Consultant TeamAssumption
Charger Maintenance Cost	5% of capex	Discussions with OEM
Cost of Grid Power (Rs./kWh)	5.45	(Rs. 5 + 9% tax)
Cost of Solar Power (Rooftop) Rs./kWh	3.5	Consultant TeamRs./kWh
%age of Rooftop solar power	15%	Consultant TeamAssumption

Cost Escalation

Cost Item / Cost Escalation	**p.a.**	**Cost Item**	**p.a.**
Diesel/Lub/Consumables	5%	Staffing	5.50%
Spares/ Reconditioning	2.00%	General (WPI)	2.00%
Electricity	1.50%		

Source: Based on Wholesale Price Indices for each category published by Government of India

Maintenance and Operating Costs

	Fuel Consumption		Maintenance Cost		Overheads	MV Tax#	Staffing Cost#
Bus Type	**Diesel# (km/L)**	**Electricity$ (km/kWh)**	**Diesel# (₹/km)**	**Electric$ (₹/km)**	**Common# (₹/Km)**	**₹/km (Nil for E-Bus)**	**(₹/km) excl. maintenance**
9m Non-AC	4.21	1.11	5.98	8.33	4.58	1.90	29.92
12m Non-AC	3.93	0.91	6.36	9.23	4.58	3.08	29.92
12m AC	2.27	0.77	16.24	10.50	5.46	3.08	29.92

Source: #BMTC Administrative Report 2019 $ Discussions with OEMs

Assumed Economic Life of the Buses

			Reconditioning		Reference
Bus Type	**Km***	**Years***	**Cost**	**Year**	
Diesel Midi	560,000	10	₹2,44,000	8	BMTC Admin Report
Diesel Std	850,000	10	₹3,40,000	8	
Diesel AC	1050,000	12	Not needed	Not needed	
9m Electric (Non-AC)	1050,000	14	--	--	2 battery life cycles
12m Electric (Non-AC)	1050,000	14	--	--	
12m Electric (AC)	1050,000	14	--	--	

* whichever occurs first

Source : BMTC Admin Report

8.3. Bilateral External Assistance to State Government Entities

Part A: Policy Guidelines for availing of external assistance by State Government entities from bilateral agencies [61]

1) Conditions for individual projects:
    a) Major infrastructure projects costing Rs.5,000 crore or more are eligible;
    b) The revenues generated from the project should be enough for servicing the loan;
    c) Project revenues should be escrowed for debt servicing.
2) Conditions for State Government entities:
    a) should be financially sound, having an average annual Revenue of not less than Rs.1,000 crore for the previous three years;
    b) should have consistent track record of positive net worth for the last three years with an average annual profit or surplus of not less than Rs.500 crore in last three years;
    c) Any deviation from these criteria shall require special justification. These criteria would not apply for new entities / SPVs.
3) Conditions for States to extend guarantee:
    a) Debt-GSDP ratio of the State is less than or equal to 25 per cent,
    b) Fiscal Deficit of the State in the previous and current year is less than 3 percent of GSDP;
    c) Availability of guarantee space as per the fiscal responsibility legislation of the State.
4) All debt servicing will be directly remitted by the concerned borrower.
5) As the Government of India will be providing a counter guarantee to the State entities, a counter guarantee fee would be payable.

[61] *Extracts from OFFICE MEMORANDUM no. F. No. ll3/2017-Japan-I, Government of India Ministry of Finance Department of Economic Affairs dated March 16, 2017*

6) Individual proposals submitted by the State Government entities should carry a clear recommendation from the Finance Department of the State Government, including provision of State Government Guarantee and justification for opting for the counter-guarantee route. The proposals should contain an analysis of the revenue generation from the project which would be used to repay the loan. While considering the viability of the project, the guarantee fees as prescribed in the General Financial Rules of the Union Government should also be taken into account.
7) Direct access to local capital markets and local bonds should be explored first before approaching external agencies. Help from credit rating agencies may be taken for this purpose. The option of external borrowing should be exercised only if the domestic lenders are not in a position to lend.
8) The State Government entities should also make efforts to utilize the option of commercial borrowings from the private sector window of multilateral financial institutions.

Posing of the Project proposal(s) for Direct Borrowing by the State Government Entities from Bilateral partners

Subject to the fulfilment of conditions mentioned above, the project proposal(s) will be posed by Department of Economic Affairs (DEA) for ODA from bilateral partners as per the following guidelines:

1) The project proposal(s) of State Government entities will be considered and forwarded by the State Government to the concerned Central Line Ministry with a copy to DEA.
2) The concerned Central line Ministry will be required to recommend the project proposal(s) to DEA.
3) Every Proposal shall require approval of the Cabinet Committee on Economic Affairs (CCEA).

Part B: Different Modes of External Assistance provided by KfW

KfW provides 3 types of assistance to state government entities as summarised below[62]:

Grants	1) Funded from the German Federal Government's budget 2) Mainly allocated to poor and poorly developed countries 3) More developed countries are also eligible for grants for projects that contribute directly to reducing poverty or to protecting global public goods such as, e.g., tropical rainforests.
Developmental Loans	1) Structured as reduced-interest loans 2) Only KfW's own funds partially secured by a guarantee line from the German Federal Government are deployed 3) Rate of interest is lowered due to grants from budget funds.
Promotional Loans	1) Can be applied for the funding of , inter alia, private and public investments in infrastructure (telecommunications, transport, energy, water supply, etc. 2) Project is appraised based on the sectoral and regional development policy principles of the German federal government. 3) The project risks and the borrower's credit worthiness must be acceptable to KfW. 4) Loans are granted at the high end of the range of concessional financing that means close to market conditions. 5) Minimum loan term is usually four years 6) Flexibility is available on the tenure, currencies and interest rate options.

[62] *Wordvorlage (kfw-entwicklungsbank.de)*