Greening of Public Transport in Pune – A Feasibility Study

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Abstract

India's commitment to Electric Vehicles (EV) is a prime program furthering the country's achievement of Sustainable Development Goal (SDG) number 7. However, in spite of the much-needed policy push, EV adoption in India has been slow, both in private ownership and in public mobility. The average Indian commuter still depends heavily on public transport such as public buses, railways and rickshaws. Thus, the success of the EV transition in India lies in the speed with which e-vehicles can be developed and adopted in public transport solutions. This study assesses the feasibility of converting the public transport fleet (buses and 3 wheelers) into e-vehicles for the city of Pune. Pune records high per capita private vehicle ownership, resulting in high traffic congestion, traffic indiscipline issues and high vehicular fatalities. It is thus imperative that not only should public transport usage increase in the city, but it should also be electric, such that sustainability goals are achieved. This study presents a techno-economic analysis of greening Pune's public transport fleet. This paper begins with section 1, which introduces the EV landscape in India. Section 2 details the Total Cost of Ownership (TCO) framework, which evaluates financial costs associated with EVs in public transport fleets. Section 3 presents model results from the TCO analysis. Payback calculations are also presented to understand the minimum number of years to realise EV investment payback. Section 4 finally concludes this paper by presenting demand-side and supply-side interventions for a speedy EV transition for public transport fleets in Pune Metro Region.

***JEL classification**:* Q20, Q55, Q56

Keywords: Green public transport, energy transition, electric vehicles, public transport transition, SDG 7, 3 wheelers, buses, India

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1. Introduction

Electric vehicles (EVs) now account for a modest portion of the mobility market in India, accounting for roughly 0.75 million in automobile sales. India targets to achieve one-third of total car sales to come from EVs by 2030 across all vehicle classes. Of the approximately 250 million vehicles on the road, two-wheelers account for 78 per cent of the overall fleet in India. Vehicle categories such as public buses, taxis, and two and three-wheelers will be the first to benefit from EVs because the country is in a primitive stage of EV adoption, and public charging infrastructure is still limited. Considering this, nine major cities and eleven intercity roads have been allotted as pilots by the Ministry of Power for EV charging infrastructure. (Ayog, 2021).

The Electric Vehicle technology landscape is ever-changing. As of today, EVs can vary depending on the kind of technology used to power them, namely Battery Electric Vehicles (BEVs), Plug-In-Hybrid Vehicles (PHEVs), Hybrid Electric Vehicles (HEVs), Fuel Cell Electric Vehicles (FCEVs) and Extended Range-Electric Vehicles (ER-EVs) (Sanguesa, 2021). Each of these technologies is heavily dependent on the battery system used within the vehicle. The recent decade has seen significant advancements in battery technology. Li-ion batteries such as Lithium Cobalt Oxide-LCO, Nickel Cobalt Manganese-NMC and Lithium Iron Phosphate-LFP are gaining popularity. These battery technologies have a longer cycle life than the ordinary lead-acid type of batteries (Ayog, 2021). The prime reason for its popularity in EV applications is due to its high energy density – more energy per unit weight/space can be stored in Lithium-ion batteries which is a crucial requirement in terms of mobility. Along with lithium-ion batteries, other types of batteries such as metal-air, solid-state, and lithium-sulphur batteries have advanced in terms of their technologies, although the most matured technology remains Lithium-Ion since it provides the greatest performance, vis-à-vis the alternatives (Sanguesa, 2021). However, the battery's efficiency depends, in turn, heavily on the charging infrastructure. Three variables within the charging infrastructure are crucial – mode of charging, level of charging and charging models. Diverse charging models, modes and charging levels have evolved in the recent year to maximise consumer benefit as well as supplier profits.

Several Indian states and union territories have implemented legislation to encourage EV and EV charging infrastructure development. The rapid rise in the adoption of EVs to meet the legislative ambitions of India will face two critical difficulties. First is the capacity to build enough EV charging infrastructure to accommodate the ever-increasing number of EVs. Second and relatedly will be the problem of integrating EVs into the electrical grid system. The timely development of optimal Electric Vehicle charging system infrastructure is critical to the success of the EV revolution (Ayog, 2021). However and above all, the greening of public transport should form a critical priority for urban local bodies to reap the benefits of large-scale public transport usage and related positive externalities such as carbon emission reduction and reduced traffic congestion, amongst others. A key variable in the greening of public transport is the analysis of the Total Cost of Ownership (which depends on both capital cost and operational costs). The TCO serves as a good indicator of total cost spread over the lifetime of public transport fleets, especially for the local municipalities, who are the primary investors and stakeholders in the said greening transition. While literature is evidently available on EV vehicle, battery and charging ecosystems, no study has yet detailed the TCO for EVs, with a focus on public transport fleets. This study aims to bridge the said gap by presenting the TCO analysis, which can aid effective decision-making in greening public transport in the urban city of Pune.

2. **Total Cost of Ownership (TCO) Analysis: Public Buses and 3 Wheelers**

The Total Cost of Ownership (TCO) analysis provides a transparent overview of the financial costs associated with EV ownership for consumers. Capital and Operating expenditure (Capex and Opex) are the two critical elements of the TCO model. Capex (also referred to as one-time cost) refers to the price of purchasing EVs, whereas Opex (also referred to as recurring cost) refers to fuel costs, labour expenses (in the case of public transportation such as electric buses as well as four-wheeler fleets), operational and maintenance (O&M) expenses, and various other miscellaneous costs. (Kumar & Chakrabarty, 2020). EV ownership is a capital-intensive proposition, whether it is for private vehicle ownership or public transport. It is also subjected to high variations. CAPEX variations arise mostly on account of the cost of batteries - which are imported, due to lacking domestic manufacturing capacities (Shrimali, 2021). OPEX variations are on account of several variables such as avoided fuel costs, overhead expenses etc. Thus TCO is only a best-guess estimate of EV ownership.

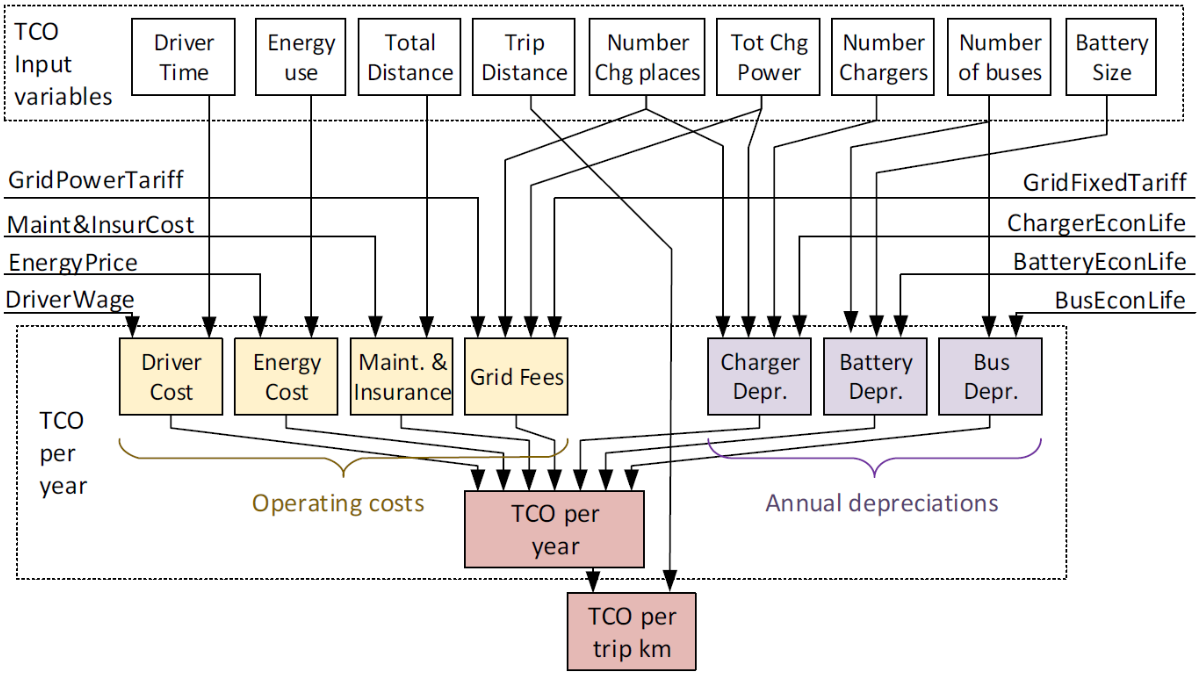
In this section, we discuss a TCO model that gives an overview of OPEX costs for running EV fleets in public transport (Institute, n.d.). The TCO model takes three types of input factors into account: capital costs, operating costs, and vehicle utilisation (or trip) information.

1. Capital costs include the purchase price of the car, the discount rate, any relevant financial incentives, the resale value, and other costs.
2. Fuel/electricity, maintenance, personnel, and other charges are included in operational costs.
3. The vehicle holding duration, average kilometres travelled per day, and the number of operating days per year is all included when calculating vehicle utilisation information.

2.1. Parameters For Determining the Total Cost of Ownership

The TCO calculations take into account the several OPEX and CAPEX components of EV ownership. EV OPEX is sensitive to 7 key factors - driver expenses, energy expenses, maintenance & insurance expenses, power grid fee, and accounting for charger depreciation, battery depreciation and vehicle depreciation (bus/3 wheeler, as the case may be) (Grauers et al., 2020). Figure 1 below represents OPEX of EV Ownership:

Figure 1: EV Ownership OPEX Variables



These seven costs are further sensitive to 9 intermediate parameters that are derived from routes and schedules. A simplistic assumption can be made that routes and scheduling considerations are the same for all vehicle types, thereby taking away this variability in OPEX calculations. These seven cost components and their connection with intermediate variables are explained as under:

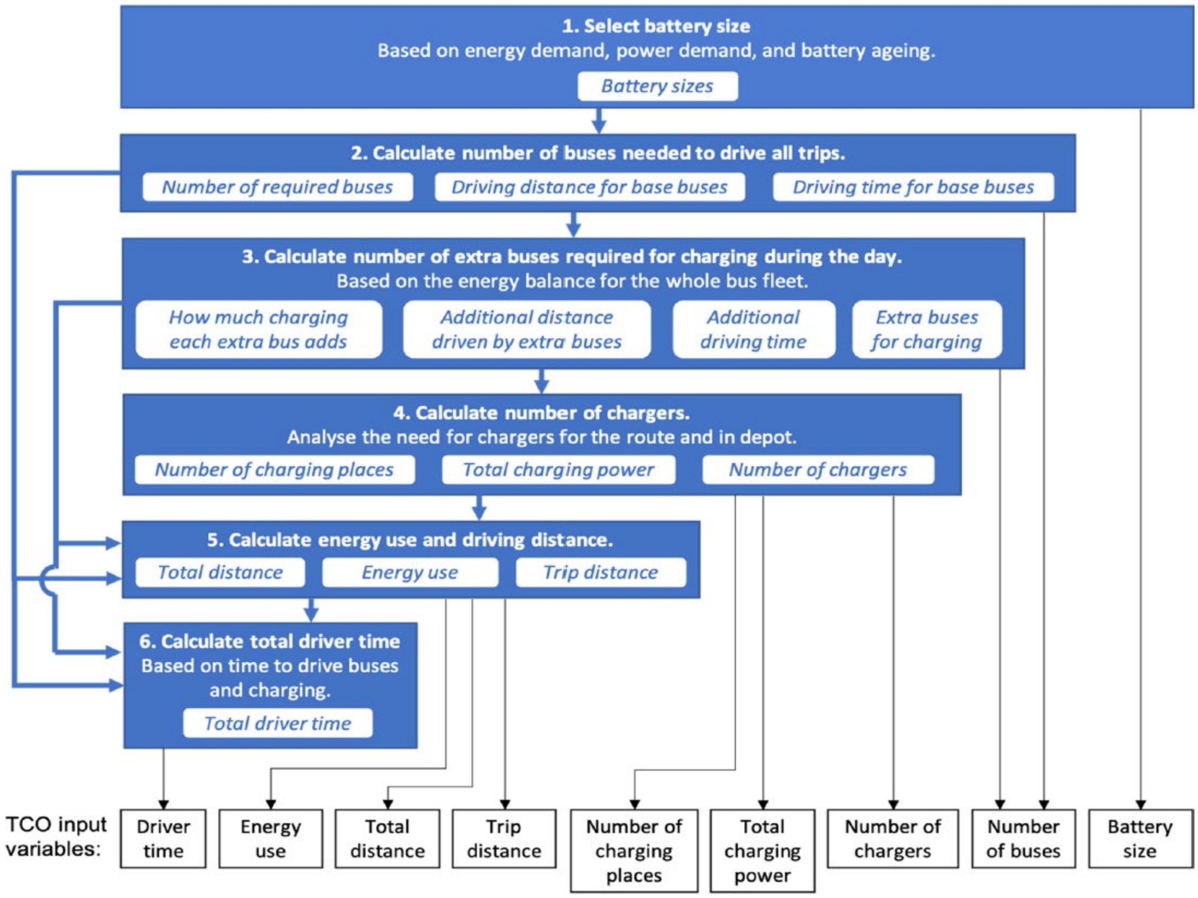
1. Driver cost = f(driver time used, hourly driver wages)
2. Energy use cost = f(energy consumption, energy consumption costs/grid power tariffs applicable)
3. Maintenance and Insurance costs = f(maintenance and insurance costs contract costs, total distance travelled by the vehicle)
4. Grid Charges = f (number of chargers accessed * total charging power consumed) * grid tariff applicable
5. Charger depreciation costs = f(number of charging places accessed, total hours of charging, charger economic life)
6. Battery depreciation costs = f(battery economic life, battery size)
7. Bus depreciation costs = f(bus economic life, number of buses in the fleet)

The sum of these seven costs provides the Total Cost of Ownership/year. Finally, TCO per year/ total trip distances travelled provides the TCO per trip km estimate (Grauers et al., 2020).

2.2. Introducing Variability in Calculating TCO Input Variables: Based on Schedule and Route Parameters

The nine factors required to determine TCO for EV buses also depend on route and trip schedule. This variability can be incorporated into the TCO model as per the schematic presented in Figure 2 below:

Figure 2: EV OPEX Variability on account of Trip Schedule and Routing



Processes 1–6 detail the procedure for calculating the nine TCO input variables, as well as the flow of information among the steps (towards the left). The white boxes depict some critical parameters computed for various phases and the output variables.

Battery Capacity and Requirement for Daytime Charging

Buses will need varying battery sizes depending on their charging approach. The battery size must be selected to fulfil a number of criteria. The battery must have sufficient capacity (kWh) to deliver the power required for the automobile's most rigorous routine, as well as some cushion for handling disruptions, which may sometimes result in truncated or entirely missed charge.

The battery must have sufficient capacity to provide the required traction power and to manage the charger's voltage. Additionally, the battery must not degrade rapidly and must have a margin that allows it to satisfy all energy and power needs even after the battery has aged. (Grauers et al., 2020).

Calculating the Number of Vehicles Required to Complete the Trips

The required number of buses is determined in two phases. To begin, the number of buses necessary to make the journeys is specified, which will be decided by the highest number of buses in use during peak hours and will be equal to the needed conventional buses. A calculation determines the number of additional buses required to provide time for charging electric buses. Depending on the schedule and charging technique, this value may be 0 or more. (Grauers et al., 2020).

Chargers

At the depot, one charger per bus is needed, with the power consumption dictated by the size of the batteries. As a consequence, one new substation must always be built, and one grid connection must be paid for at the depot. Additional chargers at both end-stops of the route, comprising three substations and grid connections, are needed for end-stop-charged buses. As a result, the total end-stop charges will equal the total number of buses plus the number of end-stop chargers. (Grauers et al., 2020)

Calculating Energy Consumption and Distance Travelled

The energy consumption of all buses may be calculated. We do not need to know which bus is travelling where for the expense analysis; we need to determine the total amount of driving. This is the total cost of driving the journeys and the cost of driving to and from the depot. (Grauers et al., 2020)

Total Driver Time Calculation

Calculating the amount of driver time required for various charge techniques is critical, since driver wages are a significant expense in many countries. Naturally, a driver is required throughout the duration of the journey, but also during the stopover period and for only a few charges. Charging at the end stops between every journey usually takes just a few minutes and requires the driver to wait. (Grauers et al., 2020).

In the next section, a snapshot of results is presented derived from the TCO analysis, disaggregated for different vehicle segments (over a ten-year holding period) at typical travel distances assumed for each segment.

3. Model Results

3.1. Electric 3 Wheeler (E3W)

EVs are more economical than their internal combustion engine (ICE) equivalents in the three-wheeler (3W) category. For business usage, with an expected daily mileage of 75km for 2Ws and 100km for 3Ws, all electric models studied had a lower TCO per km than their ICE counterparts.

We use the model with the assumed capex of 3 wheelers as INR 3,66,906. CNG-3W, Petrol-3W, and Diesel-3W all cost INR 2,40,000. Several significant inputs and assumptions were used to calculate the annual operating cost, including the cost of electricity at INR 6/kWh, the cost of petrol at INR 80/litre, the cost of compressed natural gas at INR 47/kg, the cost of diesel at INR 74/litre, the resale value at 10%, the discount rate at 10%, and a ten-year vehicle holding period. The e-rickshaw, CNG-3W, Petrol-3W, and Diesel-3W all have a mileage of 10 kilometres per kWh, 28 kilometres per kilogramme, 20.1 kilometres per litre, and 25.4 kilometres per litre, respectively.

The model results, along with model assumptions, are detailed below:

Model Assumption: E3Wheelers

Vehicle Holding Period (Year)	8
Daily Drive Distance (km)	110
Daily Drive Distance (mi)	68.35
Annual Drive Distance (km)	40,150
Annual Drive Distance (mi)	24,948

Capital costs assumptions:

MODEL	e-3W	CNG - 3W	Petrol - 3W	Diesel - 3W
Vehicle Purchase Cost (₹)	3,66,906	2,40,000	2,40,000	2,40,000
Tax (₹)	4,000	4,549	9,055	4,638
Insurance Cost (₹)	2,500	1,680	2,505	4,418
Financial Incentive (₹)	66,523			
Discount Rate (%)	10.00%	11.00%	14.00%	16.00%
Resale Rate (%)	10.00%	10.00%	10.00%	10.00%
Financing Component (₹)				
Term of Payment (Years)	7	7	7	7
Interest Rate (%)	11.00%	10.00%	11.00%	10.00%
Equity (%)	10.00%	50.00%	10.00%	10.00%
Monthly EMI (₹)	4,645	1,999	3,711	3,599
Charging Infrastructure Cost (₹)	-			

Operational costs assumptions:

Staff Cost per Month (₹)	1,000
Lithium-Ion Battery Cost (USD/kWh)	156

MODEL	e-3W	CNG - 3W	Petrol - 3W	Diesel - 3W
Fuel cost (₹/kWh; ₹/kg; ₹/L)	6	47	80	74
Capacity of Battery (kWh)	7.37			
Number of Battery Replacements	1			
Mileage (km/kWh; km/kg; km/L)	10	28.4	20.1	25.4
Annual Maintenance Cost (₹)	10,401	21,005	17,405	17,405

Table 4 appended below, shows a comparison of TCO for 3 wheelers as per fuel type. Making suitable assumptions on CAPEX, OPEX, number of life years of vehicle, and annual distances travelled, we find that e-3 wheelers are the most economical, with TCO at Rs. 2.54 per km, over the useful life of the e-3wheeler. This is substantially lower than other 3 wheelers, with the biggest saving in avoided fuel costs, even after incorporating added battery replacement costs.

Table 1: Comparison of TCO in 3 Wheelers Segment

TRAVEL DETAILS				
Number of Vehicles	1			
Life of Vehicle (yrs)	10			
Annual drive distance (KM)	40150			
Total Distance Travel (KM)	401500			
LIB Cost (USD/kWh)	156			
USD to INR	71			
General Inputs	**e-3W**	**CNG-3W**	**Petrol-3W**	**Diesel-3W**
Discount rate (%)	10.00%	11.00%	14.00%	16.00%
Resale rate (%)	10.00%	10.00%	10.00%	10.00%
Capital Cost	**e-3W**	**CNG-3W**	**Petrol-3W**	**Diesel-3W**
Total Vehicle Cost (₹)	4,93,245.66	2,94,168.93	3,47,309.49	3,35,347.88
Resale Value (₹)	493.25	294.17	347.31	335.35
Total Charging Infrastructure Cost (₹)	-	-	-	-
Misc. Cost (₹)	-	-	-	-
Financial Incentive (₹)	66,523.00	-	-	-
Total Capital Cost (₹) excluding Resale Value	4,26,722.66	2,94,168.93	3,47,309.49	3,35,347.88
Annual Operational Cost	**e-3W**	**CNG-3W**	**Petrol-3W**	**Diesel-3W**
Staff Cost (₹)	12,000.00	12,000.00	12,000.00	12,000.00
Maintenance Cost (₹)	13,602.00	24,010.00	20,410.00	20,410.00
Battery Replacement Cost (₹)*	8,163.01	-	-	

Average Fuel Cost (₹)	24,090.00	66,445.42	1,59,801.00	1,16,972.44
Misc. Cost (₹)	-	-	-	-
Total Operational Cost (₹)	57,855.01	1,02,455.42	1,92,211.00	1,49,382.44
Total Operational Cost for the life of 3W	5,78,550.12	10,24,554.23	19,22,109.95	14,93,824.41
Average TCO	**2.54**	**2.70**	**4.11**	**3.49**

3.2. Public Buses

We assume an average daily travel distance of 250 kilometres to be covered by public buses in the city of Pune. The TCO per kilometre of a 12m e-bus was compared to that of its ICE variants: 12m AC high-cost diesel bus (Diesel-HC Bus), 12m AC low-cost diesel bus (Diesel-LC Bus), and 12m CNG-bus.

The buying price of an electric bus (12m AC), a diesel-HC bus (12m AC), a diesel-LC bus (12m AC), or a CNG bus (12m AC) is INR 1,50,00,000, INR 88,00,000, INR 58,07,000, or INR 56,00,000, respectively (Tax and Insurance added separately). Several significant inputs and assumptions were used to calculate the annual operating cost, including the cost of electricity at INR 4/kWh and one battery replacement for the e-bus, the cost of diesel at INR 80/litre, the cost of compressed natural gas at INR 40/litre, the resale value at 10%, the discount rate at 10%, and the vehicle holding period at ten years. The mileage of an electric bus (12m AC), a diesel-HC bus (12m AC), a diesel-LC bus (12m AC), and a CNG bus (12m AC) is 1.11 kilometres per kWh, 2.2 kilometres per litre, 4.7 kilometres per litre, and 2.8 kilometres per kilogramme, respectively. Daily driving distance is assumed to be 250 kilometres for 365 days of the year.

Concentrating efforts on electrifying public transportation bus fleets is critical for future-proofing long-term capital investment choices. Electric buses, on the other hand, presently have a higher TCO per km than diesel (low-cost models) and CNG-fueled buses for a typical daily use of 200 kilometres.

When year-by-year TCO/km is compared (see Graphical depiction "Total Cost of Ownership over the years"), an e-TCO/km bus's becomes less than that of a diesel-HC bus after the sixth year of holding term (period for which the bus is in service, taken as ten years for the analysis). With a longer vehicle holding time, the TCO/km difference between an e-bus and its ICE equivalents narrows dramatically. Due to increased vehicle utilisation and lower purchasing costs, an e-TCO/km bus's is equivalent to that of its ICE counterparts early in the holding period. For example, with a daily mileage of 250 kilometres, the TCO/km of an e-bus reaches parity with that of a diesel-HC bus in the third year and wears off.

Model Assumptions: E-Buses

Vehicle Holding Period (Year)	**4**
Daily Distance Travelled (km)	**250**
Daily Distance Travelled (mi)	**155.34**
Annual Distance Travelled (km)	91,250
Annual Distance Travelled (mi)	56,700

Capital costs assumptions:

MODEL	e-Bus	Diesel - Bus (HC)	Diesel - Bus (LC)	CNG - Bus
Vehicle Purchase Cost (₹)	1,50,00,000	88,00,000	58,07,000	56,00,000
Tax (₹)	7,50,000	17,52,113	17,00,000	17,00,000
Insurance cost (₹)	-	-	-	-
Financial Incentive (₹)	50,00,000			
Discount Rate (%)	9.00%	11.00%	20.00%	16.00%
Resale Rate (%)	10.00%	10.00%	10.00%	10.00%
Financing Component (₹)				
Term of Payment (Years)	7	7	7	7
Interest Rate (%)	11.00%	16.45%	10.00%	15.00%
Equity (%)	40.00%	20.00%	15.00%	42.00%
Monthly EMI (₹)	1,03,092	1,42,058	82,236	62,869
Charging Infrastructure Cost (₹)	-			

Operational costs assumptions:

Staff Cost per Month (₹)	1,20,000
Lithium-Ion Battery Cost (USD/kWh)	156

MODEL	e-Bus	Diesel - Bus (HC)	Diesel - Bus (LC)	CNG - Bus
Fuel cost (₹/kWh; ₹/L; ₹/kg)	4	80	80	40
Capacity of Battery (kWh)	280			
Number of Battery Replacements	1			
Mileage (km/kWh; km/L; km/kg)	1	2.2	4.7	2.8
Annual Maintenance Cost (₹)	1,50,000	5,00,000	3,00,000	3,24,000

Table 5 appended below shows a comparative of TCO for buses as per fuel type. Making suitable assumptions on CAPEX, OPEX, number of life years of vehicle, and annual distances travelled, we find that e-buses are more economical than any other fuel type buses, inspite of a significantly higher capital cost commitment. TCO comes to around Rs. 39/km. However, e-buses TCO are comparable to CNG buses due to the fuel cost economics of CNG.

Table 2: Comparison of TCO in Bus Fleets

TRAVEL DETAILS				
Number of Vehicles	1			
Life of Vehicle (yrs) Annual drive distance (KM)	10 91250			
Total Distance Travel (KM)	912500			
LIB Cost (USD/kWh) USD to INR	156 71			
VRLA Cost (USD/kWh)	100			
General Inputs	**e-Bus (AC)**	**Diesel-HC Bus (AC)**	**Diesel-LC Bus (AC)**	**CNG-Bus (AC)**
Discount rate (%)	9.00%	11.00%	20.00%	16.00%
Resale rate (%)	10.00%	10.00%	10.00%	10.00%

Capital Cost	**e-Bus (AC)**	**Diesel-HC Bus (AC)**	**Diesel-LC Bus (AC)**	**CNG-Bus (AC)**
Total Vehicle Cost (₹)	1,84,09,707.96	1,54,45,010.31	94,78,909.35	93,33,012.19
Resale Value (₹)	18,40,970.80	15,44,501.03	9,47,890.94	9,33,301.22
Total Charging Infrastructure Cost (₹)	-	-	-	-
Misc. Cost (₹)	-	-	-	-
Financial Incentive (₹)	50,00,000.00	-	-	-
Total Capital Cost (₹)	1,34,09,707.96	1,54,45,010.31	94,78,909.35	93,33,012.19

excluding Resale Value				

Annual Operational Cost	**e-Bus (AC)**	**Diesel-HC Bus (AC)**	**Diesel-LC Bus (AC)**	**CNG-Bus (AC)**
Staff Cost (₹)	14,40,000.00	14,40,000.00	14,40,000.00	14,40,000.00
Maintenance Cost (₹)	2,15,000.00	5,65,000.00	3,65,000.00	3,89,000.00
Battery Replacement Cost (₹)*	3,72,153.60	-	-	
Average Fuel Cost (₹)	3,65,000.00	33,18,181.82	15,53,191.49	13,03,571.43
Misc. Cost (₹)	-	-	-	-
Total Operational Cost (₹)	23,92,153.60	53,23,181.82	33,58,191.49	31,32,571.43

Total Operational Cost for the life of Bus	2,39,21,536.00	5,32,31,818.18	3,35,81,914.89	3,13,25,714.29
Average TCO	**38.39**	**62.08**	**39.81**	**37.27**

3.3. Return on Investment and Payback period calculations of Fleet Replacement with EV in public transport

Pune Metropolitan Region's public transport transition plan necessitates a priority focus on E-buses. A few reasons for transitioning the city buses first are:

- City buses run a cyclical, repetitive schedule with repetitive routes at set times. This gives the city buses ample time to plan and charge them according to their route and time available for charging.
- City buses generally have many stops and halts during their rides. As a result, ICE vehicle efficiencies are low. Hence, transitioning to electric buses will improve the efficiency of the buses at lower speed ranges as electric vehicles can regain the energy lost by regenerative braking.
- IC engines need to power other loads of the vehicles, such as the air conditioning and other power elements of the vehicles. When the vehicle is at a halt, the engine should idle to supply this demand. And the efficiency of IC engines is very low when the engine idles.

This can be overcome by transitioning to electric buses. Powering these functions through an electric motor/engine greatly saves fuel and reduces emissions.

- IC engines emit many pollutants into the environment, especially at low speeds when the buses accelerate from a halt, and the metro cities have very bad AQI, sound pollution etc. these can be avoided/reduced by transitioning to electric. The electric motor can boost the Rotations Per Minute (RPM) of the engine at low speeds with high efficiency and very silently too.
- City buses travel more number of kms, resulting in high fuel usage. Electrifying the city bus fleet would result in avoided fuel cost inflation and contribute to a greener environment.

Given this, there is a clear case for PMR to consider ICE bus fleet replacement with E-Buses.

To get a better understanding of the costs involved and the Return of Investment (ROI) for this exercise, we present below a simulation exercise, with suitable assumptions inputted in when necessary.

Considering a 9m electric bus and calculating the ROI for PUNE city:

For calculating the ROI for the E-bus, certain base parameters are to be considered. They are:

Number of buses: 1

Lifetime of a bus: 10 years

Number of kms travelled per day: 200

Number of working days per year: 365 (considered)

bus type	9m 180Kwh	9m 102Kwh	diesel bus
Range	300km	150km	
Purchase Cost	1.2Cr	80L	60L
Tax	7.4L	4.5L	16.8L
Slow Charger Cost	7.5L	7.5L	
Fast Charger Cost	37.5L	15L	
Installation Costs	1.5L	1L	
Full Staff Cost	1.5L	1.5L	1.5L
Fuel Cost	6/kwh	6/kwh	95/l
Mileage	0.77km/kwh	0.77km/kwh	2.75km/l
Annual Maintenance	4.6L	4.6L	9L
Battery Cost	12,000	12,000	
Total Battery Replacement Cost	7.5L	3L	

bus type	**9m 180Kwh**	**9m 102Kwh**	**diesel bus**
TCO Per Km	69.5/km	53.3/km	61.78/km
TCO Per Km After FAME Subsidy	54.5/km	44.61/km	61.78/km
TCO per day	Rs. 10,900	Rs. 8,922	Rs. 12,356
TCO per month (30 days)	Rs. 3,27,000	Rs. 2,67,660	Rs. 3,70,680
TCO per year	Rs. 39,24,000	Rs. 32,11,920	Rs. 44,48,160
passenger capacity	30	30	30

- We make the following assumptions:
  - One trip = 40 kms, 30 passengers
  - Round trip = 80 kms, 60 passengers
  - Per round trip cost of ticket = Rs. 100
  - Total revenue from one round trip = 60*100 = Rs. 6000
  - For three such trips (3 round trips @ 60 kms per trip = 180 Kms; maximum distance that can be covered is 200 Kms) , daily revenue stand at Rs. 18,000 per day.
  - As given in the table, The TCO per day of a 9m electric bus is Rs. 10,900. Therefore net revenue per day Rs. 7,100.
  - Annual net revenue = 7100*365 (no of operational days for the bus) = 25,91,500
  - Capex investment (including charger and battery costs) = Rs. 1,70,00,000 (1.7 crores)

Given the above-made assumptions, it can be said that payback for investing in a 9m electric bus can be recovered between 6-7 years. This is an important pointer for Urban Local Bodies, giving them a sense of a quick payback on their investments in e-buses.

4. Recommendations for Pune Metro Region

Pune Metro Region has the vision to be carbon neutral by 2030. EV transition, especially in public transport fleets, will greatly accelerate the pace at which Pune can achieve carbon neutrality. Based on the extensive literature review and analysis presented in this study, we present the following key recommendations for consideration by PMR, segregated into demand-side and supply-side interventions. While the demand-side recommendations are aimed at boosting EV demand, supply-side interventions are aimed at incentivizing an EV manufacturing ecosystem.

4.1. General Recommendations

1. Pune Metro Region would benefit greatly by replacing the 3 wheeler autorickshaws with e-3 wheelers. Although the current 3 wheeler fleets are largely run on CNG, which is in itself a cleaner fuel than petrol/diesel, e-3wheelers would be even cleaner and, at the same time, come at a lower Total Cost of Ownership (TCO) at (Rs. 2.54/km vis-à-vis Rs. 2.70/km).

2. The transition to E-buses may wait for PMR as the TCOs are slightly on the higher side owing to high capital cost commitments. Financial payback for e-buses are between 6-7 years, as per the model presented in this analysis, depending on capital costs, vehicle range, number of trips possible, number of passengers and ticket prices.
3. The success of EV transition depends on the battery and charging infrastructure. Hence, in addition to developing battery charging stations, PMR would also benefit by developing battery swapping stations. ULBs can set up these stations in non-busy routes which have idle land capacities available. Private investors can also be invited for the development of charging and swapping stations on a PPP mode.
4. While developing charging stations, new charging business models can be considered by PMR, such as the Vehicle to Grid (V2G) model. In order to facilitate this, it is essential that an attractive and efficient Time of Use (ToU) power tariff structure is designed, by the state electricity regulatory commission.

4.2. Recommended Demand Side Interventions:

1. The State can identify dedicated Green Routes – highways or roadways that permit 100 per cent EV transportation along these routes. This would be beneficial to boost demand since a green route is more conducive to EV speeds, ranges, and need to charge intermittently. Setting up EV charging stations (preferably every 50 kms) will be an essential pre-requisite in this case. This will help in higher adoption by easing adopting concerns surrounding speed, range and charging anxiety in end consumers.

2. Urban Local Bodies (ULBs) can provide property tax rebates to set up charging infrastructure on private land/property.

3. The State can also consider setting up EV manufacturing units in the underdeveloped regions of the State. This will not only create jobs in these regions but will also boost demand for EVs in the unexplored areas of the State

4.3. Recommended Supply Side Measures:

1. A minimum 10% of total parking space can be reserved for E2Wheelers in housing societies and malls. Separate charging hubs should be created for e-buses. Charging can also be integrated into such spaces, at cost/user fees, to optimise consumer charging time.

2. The state can also consider establishing battery swapping stations (where a fully discharged battery can be exchanged for a fully charged battery). Battery swapping is an upcoming and innovative supply-side solution.

3. Energy operators – agencies that can set up captive renewable energy capacities (such as solar carports or independent RE power plants) should be given the advantage of energy banking. Any excess power not utilised in EV charging should be allowed to be banked with the local power utility for a period of one year.

4. Charging operators (agencies that set up, operate and maintain charging stations) can also be incentivised to act as end-of-life battery recycling agencies. Under this arrangement, charging operators may not need to bear the sole responsibility but can transfer the recycling burden to battery manufacturers under an Extended Producer Responsibility (EPR) model or share the burden under a Partial Producer Responsibility (PPR) model. For this, charging

operators can amortise the recycling costs in user charges that is charged to end users. This exercise calls for detailed calculations of recycling costs for a successful amortisation schedule, before introducing it in the market.

5. Used EV batteries can be used to support off-grid solar energy projects, and can be used to create mini-grids and micro-grids in energy deficit regions in the State. The success of this model will depend on the re-usability of used batteries. EV owners can be provided with a cash-back to return used batteries, instead of dumping them, thereby avoiding environmental degradation.

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