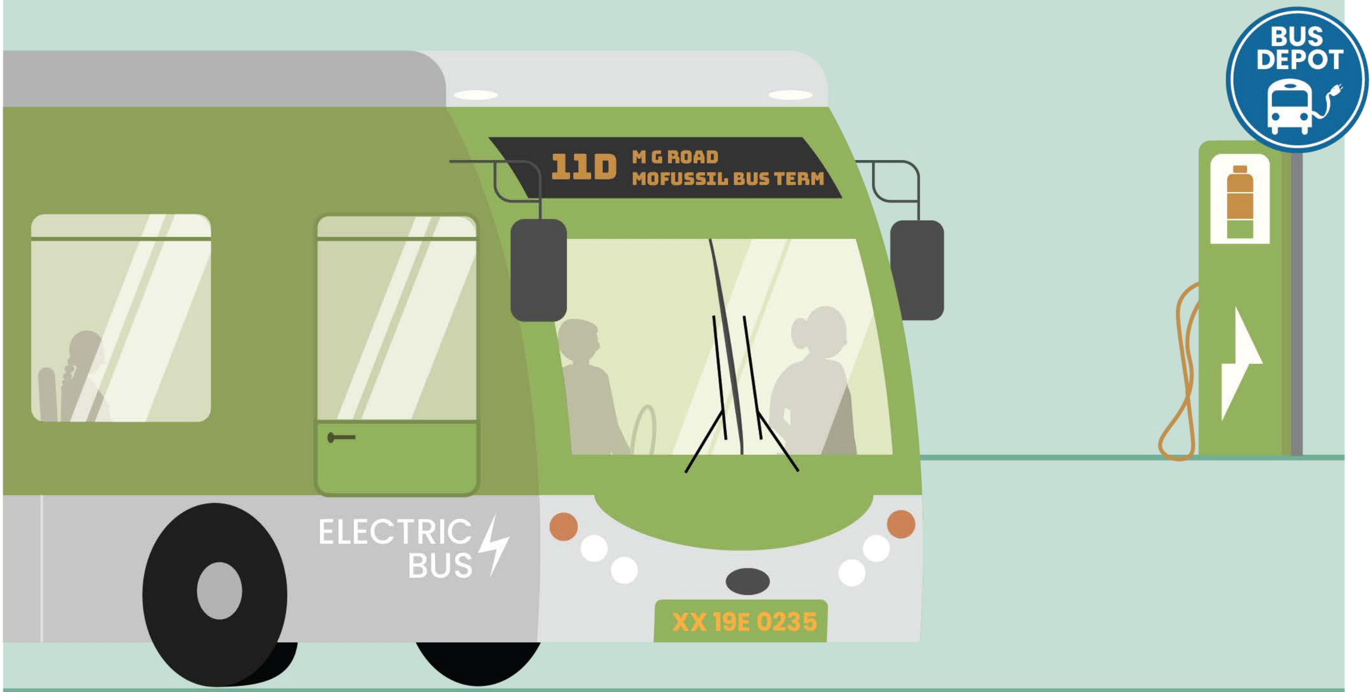
E-BUS BASICS

A GUIDE FOR CITIES TO TRANSITION TO ELECTRIC BUSES

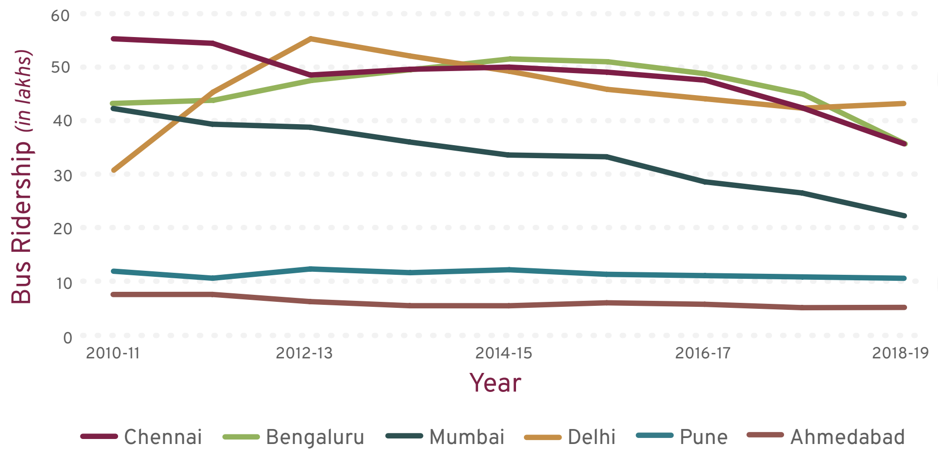


Prepared by:
ITDP INDIA

For:
Association of State Road Transport Undertakings

Why does India need buses?

We do not have enough buses. Their numbers have not increased and their level of service has not improved. So, bus services do not match up to people's expectations of comfort and time. This results in overcrowding and poor services, leading to a drop in ridership, as people shift to other modes of transport.



4.5x Increase in the ownership of private vehicles

So? This leads to two main problems **Traffic congestion and Pollution**

Procuring **more buses** can help **reduce congestion and pollution.**

10x **Buses can carry 10 times more** people than private vehicles.

CH_4 CO_2 NO_x They also have **lower emissions per person per trip** compared to private vehicles.

Why do we need electric buses?

Electric buses provide an opportunity to transition directly to less polluting buses that **run on cleaner energy, and reduce our dependence on fossil fuels.**

Most buses in India have **Internal Combustion Engines (ICE) that run on diesel.** Some run on Compressed Natural Gas (CNG), and are less polluting than diesel, but are affected by possible shortages in CNG supply.

There is an **economic burden of increasing fuel costs** on cash-strapped transport agencies due to reliance on fossil fuel imports.

Electrifying bus fleets can help reduce reliance and expenditure on fossil fuels, and reduce pollution. E-buses have zero tailpipe emissions and 30-40% less emissions overall.

E-Buses offer

- Lower running cost
- Lower cancellation rate
- Better earnings per kilometre
- Better energy efficiency
- Better quality of services

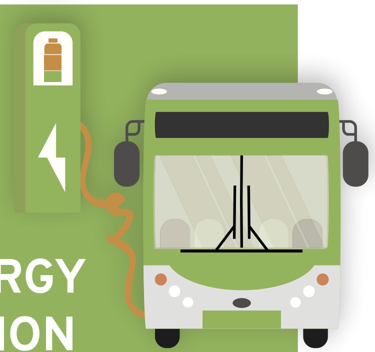
E-Buses vs. ICE Buses
The case of Pune's PMPML

Comparison of electric and ICE buses:
ITDP analysed the operational data of PMPML—the bus transport agency for Pune and Pimpri Chinchwad—from February 2019 to January 2020, to assess the **feasibility of e-buses compared to ICE buses in the Indian context.**

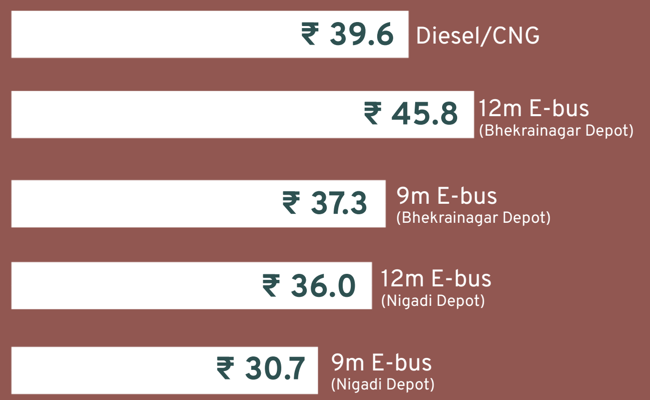
35% MORE RIDERSHIP

Passengers carried per bus per day for e-buses was 35% more than that of ICE buses. A survey by PMPML showed **78% of respondents preferred e-buses**, for various reasons—smoother rides, lesser noise, comfortable seating, and air conditioning.

50% LOWER ENERGY CONSUMPTION



E-buses had a **lower energy consumption** in comparison to both diesel and CNG buses. A lot of energy is wasted in diesel and CNG engines.



COMPARABLE EARNINGS PER KILOMETRE

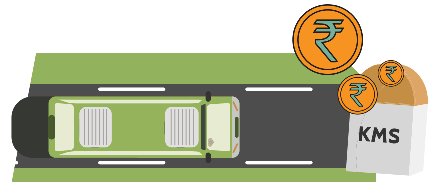
Depending on the routes selected for e-buses, earnings per kilometre for e-buses were less or more than that of ICE buses.

2X MORE MILEAGE

E-buses had far **better mileage** per unit energy as compared to diesel and CNG buses.

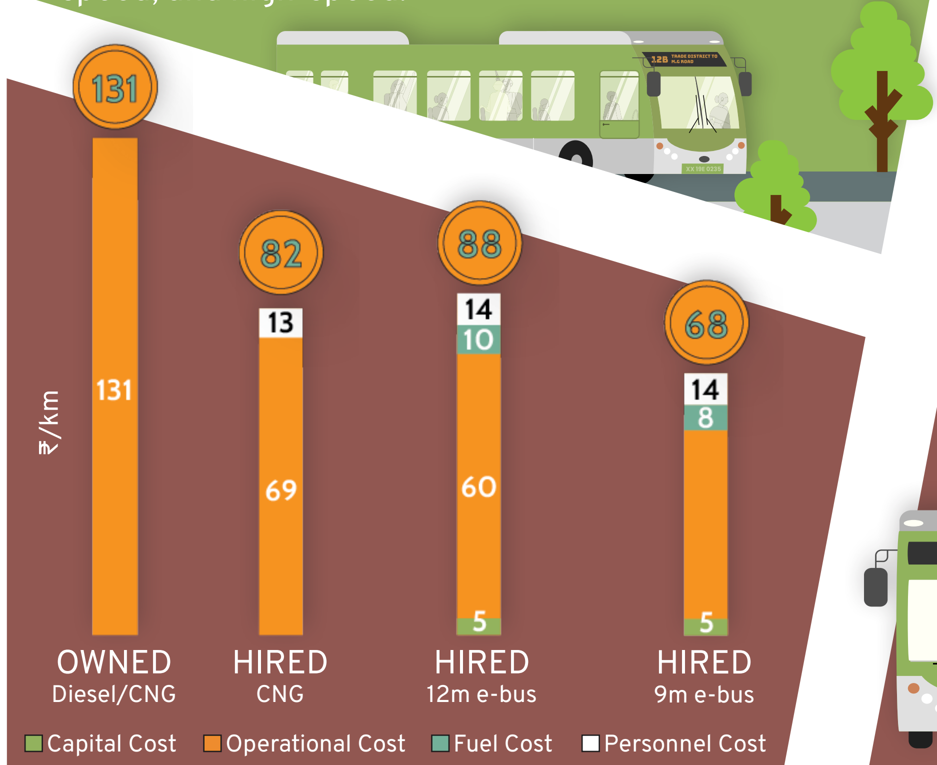
LOWER EMISSIONS

E-buses have zero tailpipe emissions. Additionally, overall greenhouse gas emissions of e-buses were lower than ICE buses in all traffic conditions—low-speed, medium-speed, and high-speed.



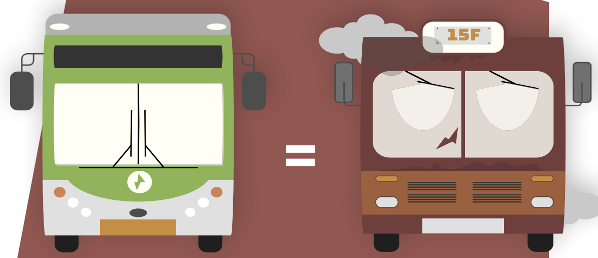
~50% LESSER COST PER KM

PMPML's e-buses were **almost 50% cheaper** to operate than their ICE buses.



TOTAL COST OF OWNERSHIP

Calculations by ITDP show that the **TCO of PMPML's e-buses almost matched that of high-cost AC diesel buses** when they were operated for over 200 km/day.



EQUAL PERFORMANCE

E-buses were able to match the performance (operated kilometres per bus per day) of ICE buses, with effective planning and opportunity charging.

1/3RD FUEL COST PER KM

Lower fuel costs can bring down operating costs. Fuel cost constituted more than 15% of PMPML's operating costs. **E-buses had only one-third the fuel cost of ICE buses.**

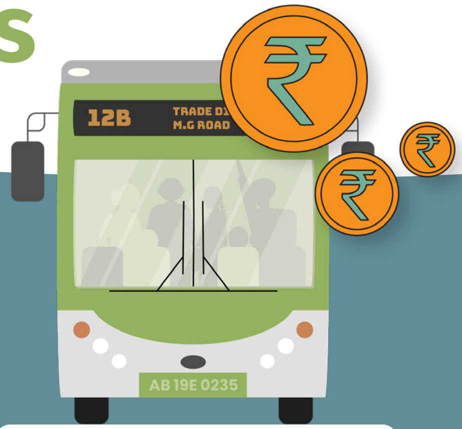
LOWER CANCELLATION RATES

At 21%, **ICE buses had a significantly higher cancellation rate** than e-buses (14%). ICE buses have more moving parts and hence are more susceptible to breakdowns.

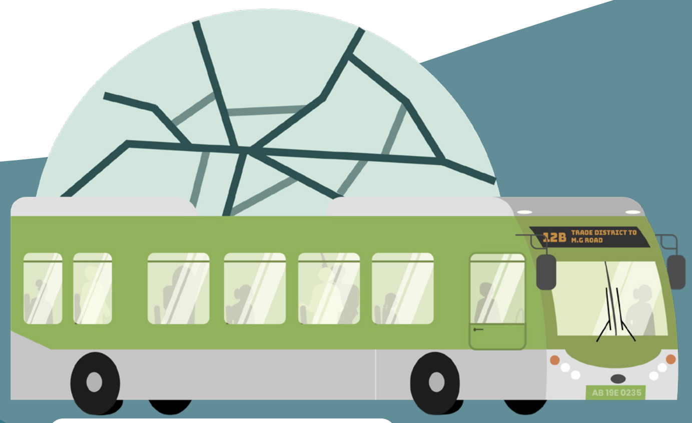
Transitioning to e-buses

How to plan & operate e-buses?

1. Prepare a long-term TCO analysis

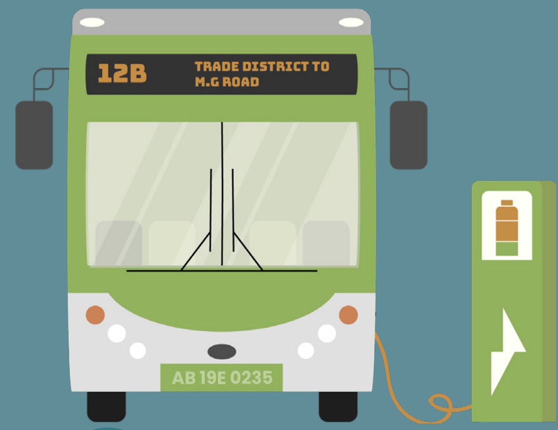


2. Select routes for operations



3. Identify depot locations

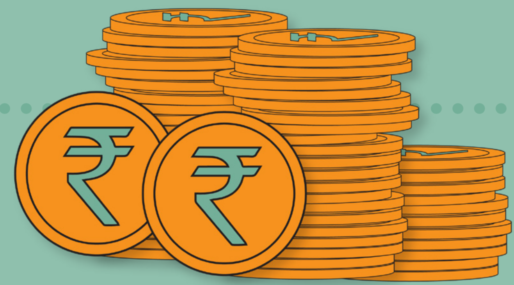
4. Plan for charging infrastructure



How to procure & finance e-buses?

1. Select procurement method

2. Select financing method



How to monitor & evaluate e-bus operations?

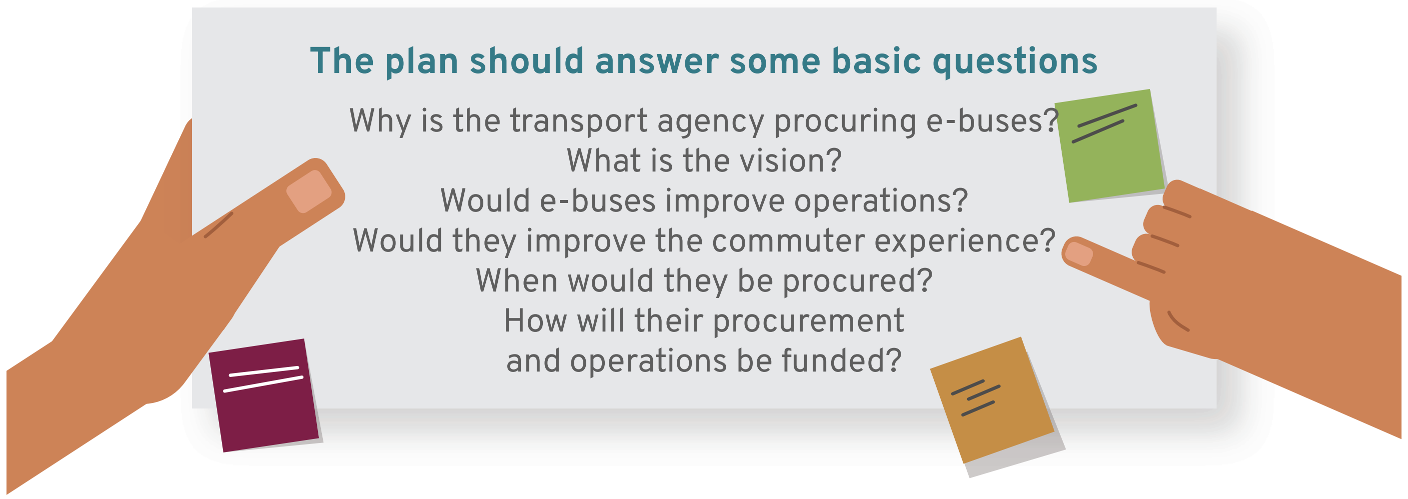
1. Define Key Performance Indicators(KPIs)

2. Collect relevant data

3. Analyse data to assess performance

How to plan and operate e-buses?

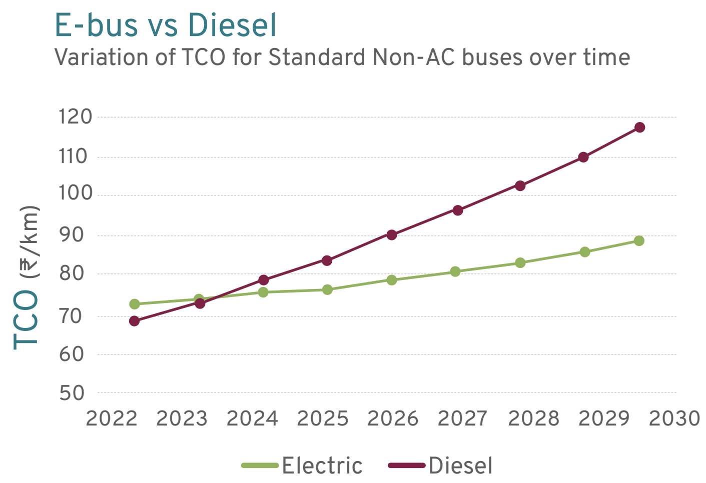
Before procuring e-buses, transport agencies should prepare a **long-term plan for e-bus operations** to ensure financial viability.



Step 1 Prepare a Total Cost of Ownership (TCO) Analysis

What is a TCO Analysis?

It is the total lifetime cost for procuring and operating a bus. It takes into account the initial capital cost, the operational costs, and how many kilometres the buses are expected to run per day.



Why is a TCO Analysis important to transport agencies?

It helps make calculated decisions on **selecting the right bus technology, charging infrastructure, daily distance, deployment of staff, and the level of subsidy** to be provided. A route-level TCO comparison of electric and ICE buses can also help cities plan and deploy e-buses more effectively.

The TCO Analysis can demonstrate the comparison between the TCO for electric and ICE buses—with time, e-buses have a lower TCO compared to ICE buses—to make a case for replacing ICE buses with e-buses.

Step 2 Select routes for operations

The success of e-buses is determined by the routes selected for operations. The routes selected—and factors like the number of stops, depot locations, and the size of the fleet—impact the optimisation of charging infrastructure, impacting the TCO. **The goal of effective route selection is to reduce the replacement ratio of buses.** Replacement ratio is the ratio of e-buses required to replace ICE buses to provide the same level of service.

How to evaluate routes for operations?

- **Effective kilometers**

The more an e-bus runs, the lower the cost. Prioritise **routes that are 180-230 km-long** to ensure full utilisation of battery and reduce the replacement ratio with bigger battery capacities (>300 kWh). For routes longer than 200 km, ensure intermittent charging at depots.

- **Replacement ratio**

E-buses need time to charge once their batteries are discharged. Select routes to **minimise the replacement ratio—such that one electric bus can replace one diesel bus** to bring down the overall replacement ratio and consequently, the costs.

- **Operational Efficiency**

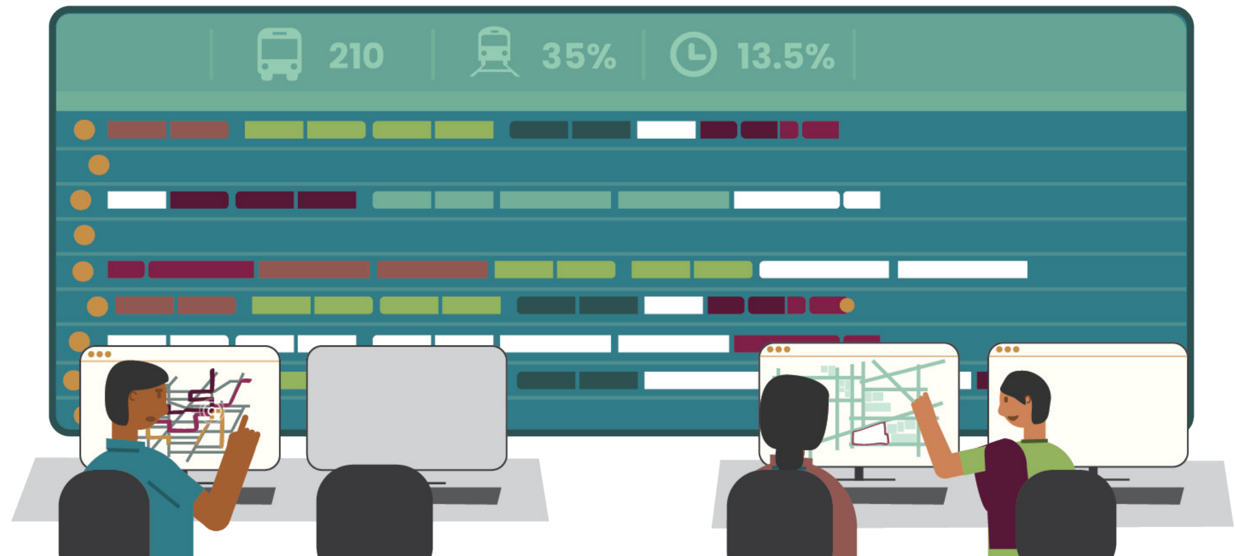
Introduce **new schedules or change existing schedules** along the selected routes to **ensure efficient running** of buses.

- **Scheduling**

Select the depots for electrification, then reschedule e-buses through the selected depots to **reduce dead kilometres**—the distance travelled by buses to depots after completion of routes, when no commuters are travelling.

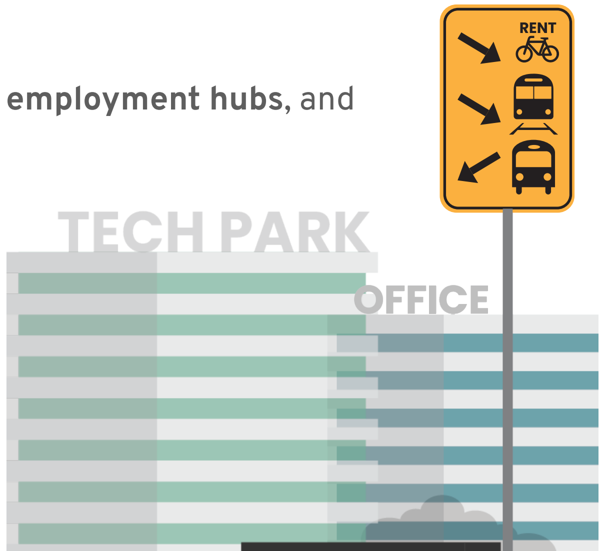
- **Ridership**

Prioritise routes with **consistent and predictable ridership** to make the most efficient use of the battery, and ensure the benefits of e-buses are enjoyed by a maximum number of commuters.



- **Coverage**
Prioritise **routes along high-density areas** and **major employment hubs**, and **routes connected to other transit modes.**

- **Congestion**
E-buses would have a **significant advantage in mixed traffic lanes,** since they consume negligible amounts of energy when stuck in traffic and have better efficiency at low speeds, compared to ICE buses (which burn fuel when idling and have poor efficiency at low speeds).

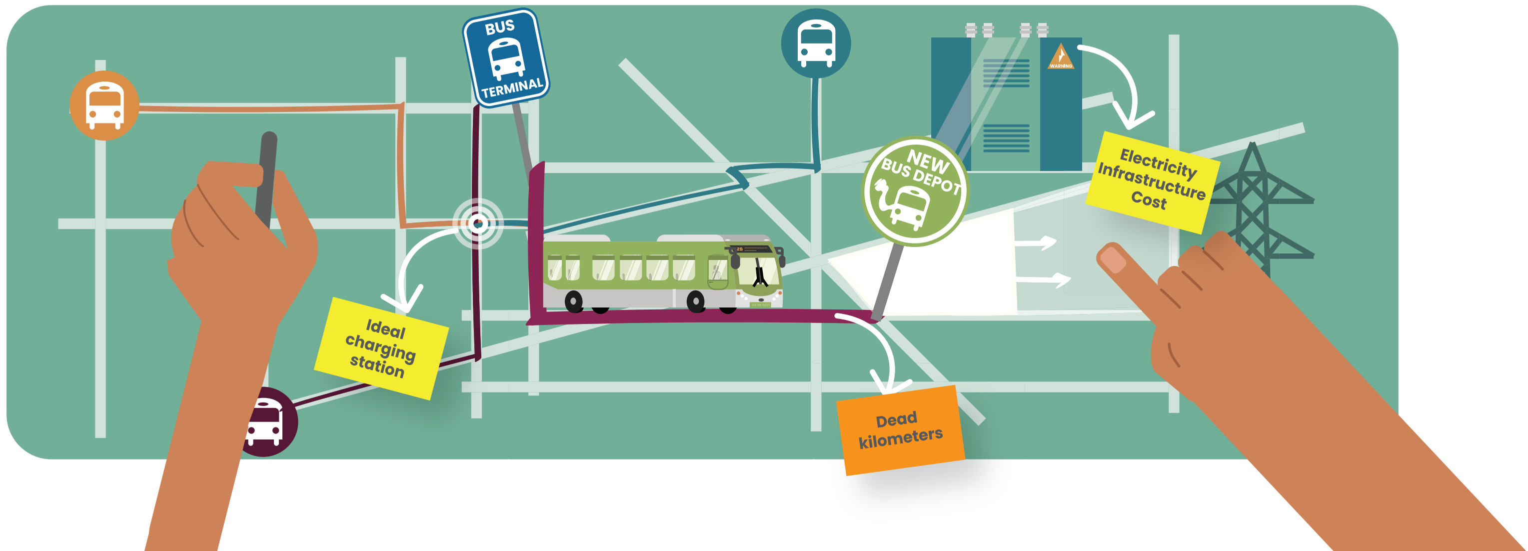


- **Terrain**
Going up slopes requires higher battery usage but e-buses have **lower battery usage on the downward slope.** E-buses also have regenerative braking–the ability to recharge the battery while coming down the slope–further **reducing the net energy consumption.** In areas with rolling terrain, carry out route-level simulations to identify the most feasible routes.

Step 3 Identify depot locations

Why is it important?

Availability of space for e-buses at existing depots is a concern due to limited space for parking and manoeuvring, development of grid infrastructure and setting up for battery charging/swapping stations. **The right locations can help optimise operations.**



How to select the depot locations for e-buses?

Depot locations should be selected, striking a fine balance between **proximity to substations, proximity to route terminals, and availability of adequate space for e-bus infrastructure and its expansion.**

Depot locations should be selected considering 4 factors.

- **Minimum electricity infrastructure cost**
Conduct an evaluation of current infrastructure at depot and terminal locations. Some may only need slight upgrades, others may need setting up of sub-transmission lines and substations. Selecting a **location close to existing substations** can help reduce the cost of new infrastructure. The cost of extending a 22KW line by 1 km is ~INR 1 crore (~USD 125,500).

- **Maximum usage of charging infrastructure**
Select **locations in high-demand areas with multiple routes passing** to increase the utility of the infrastructure. Also explore smart charging opportunities, and support the implementation of dynamic tariff schemes (such as time-of-day and time-of-use tariffs).

- **Adequate space, including space for future expansion**
E-buses require more space to access charging infrastructure. Assuming one charging station for every 4 e-buses, 25% of buses would be parked at charging bays and the rest can be parked in blocks like the ICE buses.

Parking and refuelling area per bus

E-bus without block parking	90 m²
E-bus with block parking	64 m²
ICE bus	56 m²

Ensure the location has 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.

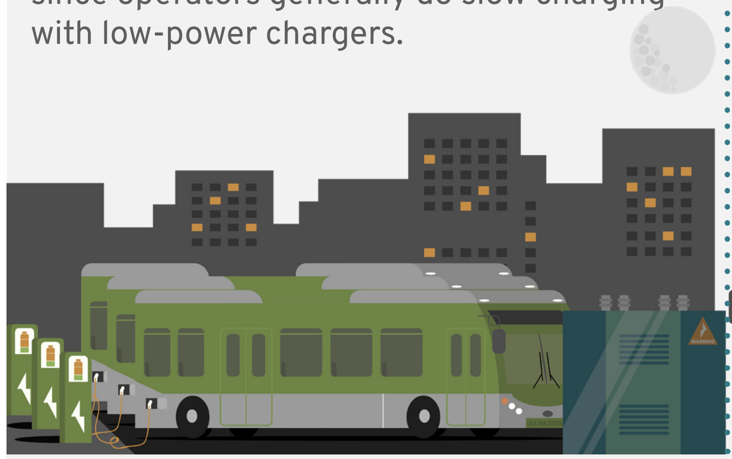
- **Minimum dead kilometres**
Select **depot locations as close as possible to route terminals.** Find locations with large space availability, but which do not increase dead kilometres. This can be addressed by setting up opportunity charging stations where possible to increase the range of buses.

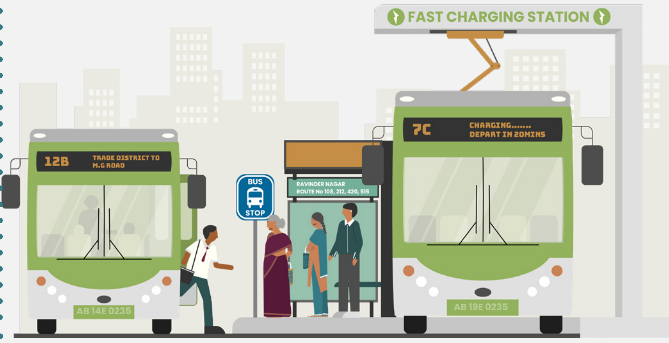
Note Setting up an Intelligent Traffic Management System is critical to schedule e-bus charging to optimise the usage of charging infrastructure.

Step 4 Plan for charging infrastructure

Select the charging technology

Depot charging	vs	Opportunity charging
Since buses typically operate during the day, e-buses can be **charged overnight at depots**. This gives a significant advantage in **freedom of navigation, route selection, and lower range anxiety**. But this makes batteries heavier leading to lower passenger carrying capacity. Cost may be relatively low since operators generally do slow charging with low-power chargers.		This requires **charging stations at regular intervals** and works best if a high capacity grid connection and the space required is available. This reduces the freedom of navigation and could lead to higher infrastructure cost.





Factors that influence charging locations

Depot charging	Factor	Opportunity charging
For trips within the battery range	0250 Average trip length	For trips that are longer than the battery range
When traffic conditions are unpredictable	Delays	When traffic conditions are predictable on the route or a dedicated corridor
Where a high capacity grid connection cannot be established	Connection capacity at terminal stations	Where a high capacity grid can be established for fast, high-capacity charging to operate 300-600 kW
Where depots can support upto 150 buses	Space	Where space is available for charging infrastructure

Choose the right charging strategy

Option 1

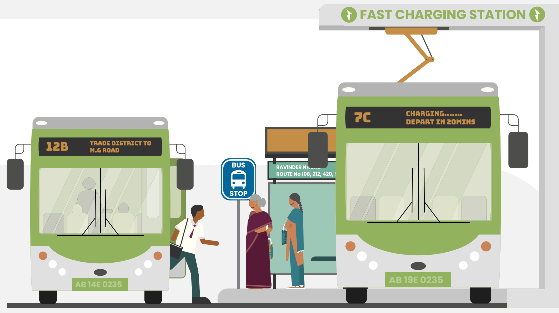
Overnight Charging at Depots

This is **sufficient when battery capacity gives enough range to cover daily trip length.** Lower cost for chargers, but increased battery weight leading to lower passenger capacity.

Option 2

Overnight Charging + Opportunity Charging at Depots

During off-peak hours, **buses can go back to the depots to charge**. Same depot chargers can be used and smaller batteries are sufficient.



Option 3

Overnight charging at Depots + Opportunity Charging at Terminals or Enroute

Buses can be charged en-route or at terminals, to reduce dead kilometres travelling to-from the depot. This reduces battery size and increases flexibility but increases cost and complexity with high power fast chargers needed to be set up outside depots with high grid capacity.

How to procure and finance e-buses?

Procurement and Financing

are interdependent aspects of acquiring any asset for public transport. The method selected for these is **a strategic choice which also impacts the cost of procurement**.

•Procurement method

Procurement depends on

- Technical competence
- Infrastructure requirements
- Operational planning
- Ability to raise capital and cost of funding
- Organisational preference etc.

Step 1 Select Bus Contracting Structure

From the options available, select a contracting structure that best suits the contextual needs of your city.

	Owner-Operator Model	Management Contracting Model	Franchising/ Licencing Model	GCC	NCC
Who owns the buses?	Transport agency	Transport agency (could be transferred to the private operator on meeting certain conditions)	Transport agency	Private operator	Private operator
Who operates the buses?	Transport agency	Private operator—within predefined quality and service parameters	Private operator—assigned to identified route/ services	Private operator	Private operator
Who collects the fare and bears the ridership risk?	Transport agency	Transport agency	Transport agency	Transport agency	Private operator
Who provides capital and policy support?	Municipal/ provincial/ national government(s)	Transport agency	Licensee pays a predefined license fee OR Transport agency pays a subsidy/grant amount in case of loss-making but socially desirable services	Transport agency pays the operator based on fleet size and/or kilometres run. Transport agency frames rules, policies, routes, fare structure, and other service parameters	Operator pays a premium OR receives a fixed subsidy based on kilometres run. Transport agency frames rules, policies, routes, fare structure, and other service parameters
Where is this best 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.	Where the transport agency already owns the buses and wishes to privatise the operations or private operators do not have the capability or willingness to acquire and finance the buses.	Where ridership patterns are well established and the transport agency wants to minimise its involvement in operations.	Markets where accurate revenue forecasting is difficult, and transport agencies have a credible track record of payments	Established markets where the ridership levels have stabilised and fare revisions are predictable
Examples	Mumbai, Kochi, and Bengaluru	Indore, Ahmedabad, Amritsar, and Surat	Mira Bhayander (2005-2017)	Delhi, Indore, and Ahmedabad	Bhopal and Jabalpur

Step 2 Fix Contract Duration

E-buses have fewer moving parts and are therefore commonly expected to last longer. But their capital cost is very high, requiring a longer period for recovery. Another factor is that batteries are generally replaced around the 7th year of operations. The battery is the most expensive component of the e-bus costing up to 30-40% of the initial capital expenditure.

What is recommended?

Best practices on public transport concessions recommend a **contract period between 10-12 years** for e-buses.

Hence, **the duration of the contract has a bearing on whether or not the battery is replaced** and if so, how much life of the second battery remains unused at the end of the contract.

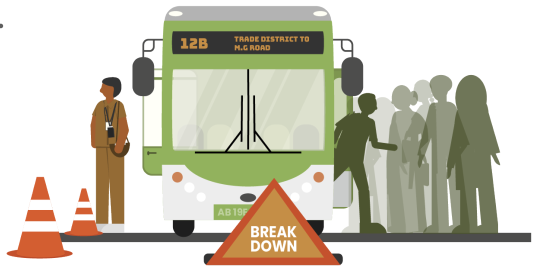
4 Factors that determine Contract Duration

1 Flexibility to change policies/clauses

Longer duration hinders the ability of the agency to realign the services with user needs and bring in changes such as less-polluting vehicles, route rationalisation etc.

2 Useful life of assets

Shorter periods result in partial utilisation of the assets. But for longer periods, overuse of the assets beyond economic life may result in higher operations and maintenance costs or lower quality of service (user comfort, reliability, safety etc.)

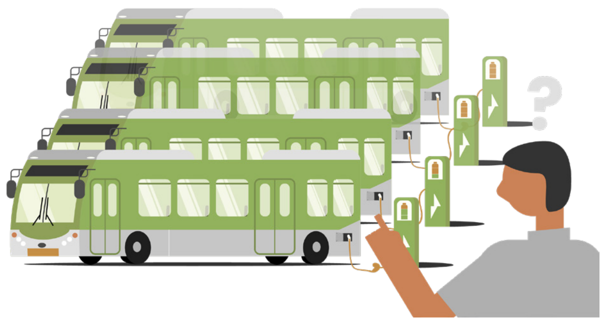


3 Investment needed to be made by the operator

If the operator is required to invest in transport infrastructure, the contract period may be longer.

4 Asset specificity

If assets acquired can be used elsewhere without significant cost, the period may be short e.g. diesel buses after their prime use can be used for school or corporate staff transfer. With articulated buses or e-buses designed for a particular route, it may be difficult or uneconomical to use them elsewhere.



Step 3 Select Remuneration Structure

The remuneration for e-bus operations **needs to be structured in a way that operators prefer the running of e-buses over ICE buses**. For e-buses, the fixed costs far outweigh the variable costs and therefore a predominantly variable remuneration system will be unsuitable.

NCC or Route Permit/License

The operator is **compensated for services mainly from the passenger fare**. Depending on the profitability of the route, the operator may pay or receive additional amounts from the transport agency.

Options in GCC

Fixed price (Price per day) | Price per passenger-km | Price per vehicle-km | Price per vehicle-hour | Price per passenger

Each structure has its pros and cons and cannot be universally applied. A mixed method can help overcome the limitations of each method.

•Financing method

Based on the contracting structure, there are different financing options.

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)

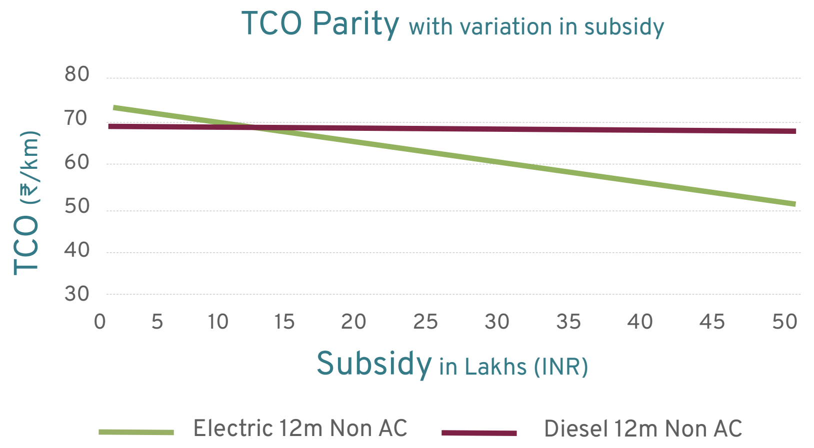
Strategies for financing e-buses

1 Traditional Financing

Using **grant funds** received from the government and/or **internal accruals and loans**

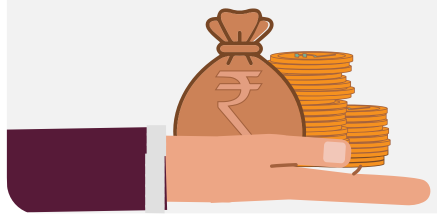
Issuing **municipal green bonds**

Getting **financial assistance** from multilateral and bilateral overseas development financing agencies
Eg: World Bank, Asian Development Bank, KfW etc.



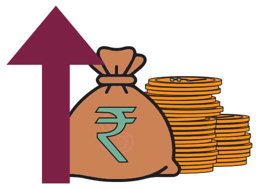
Example

Loan from KfW to the Government of Tamil Nadu for 12,000 Euro VI diesel buses and 2,000 e-buses

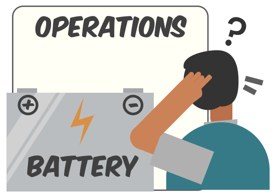


2 Bus Leasing by Manufacturers

Bus leasing can solve many issues with e-buses, including –



High investment requirement



Uncertainty with operations and battery life/replacement costs

Technological obsolescence

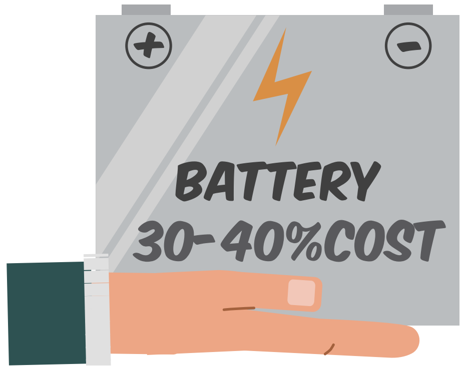
Operators can get buses on operating lease or a capital lease from the manufacturers, along with maintenance and service support. **It helps the operator to achieve the advantage of the lower lifetime TCO of e-buses from day one and provides time to develop bus operator's confidence in the technology.**

Transport agencies need good financial ratings or a backing from the government for manufacturers to extend these facilities. And manufacturers will also need financing for funding the manufacturing cost of the buses since the value of the bus is realised only over the period of the lease contract.

Example

Loan from Green Climate Fund to Mytrah Mobility Solutions to manufacture 5000 e-buses.

3 Battery Leasing



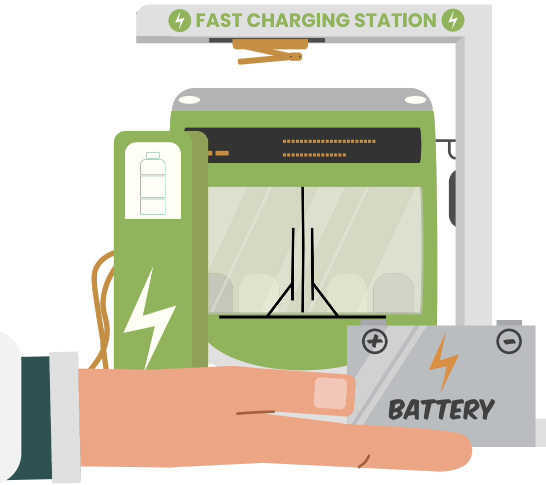
At 30-40% of the total cost, the battery is the most expensive component of the e-bus. **Leasing the battery from the manufacturer can lower the upfront cost for the operator.** The lease charges can be accommodated due to the savings in operating costs.

Example

Proterra, USA in partnership with Mitsui (financial institution) provided this model in Park City, Utah

4 Separation of Bus Ownership and Bus Operation

Ownership of e-bus assets—charging infrastructure, bus, and batteries—can be transferred to new players who have capital available to make the investments. Operators could then lease e-bus /components from these asset owners. **This mitigates the risks for operators and distributes risk across actors.**



Example

Transmilenio, Bogota launched a dual concession scheme that separates the acquisition and supply of the e-buses from their operation and maintenance

5 Pay as you Save (PAYS®[49])

PAYS model helps in overcoming barriers to investment without imposing additional liabilities on operators (unlike loans or leases). The mechanics of the PAYS model is as follows:

- A utility provider invests in batteries and charging infrastructure for e-buses thereby reducing the upfront cost. The provider leverages its access to capital to expand its revenue base as it assures the business of supplying electricity for charging e-buses.
- The utility provider then provides charging service to the bus operator. The tariff allows the utility provider to recover its costs within the warranty period through a fixed charge on the bus service provider's regular monthly electricity bill. This approach enables bus service providers to pay for the costs of the batteries and charging stations over time rather than all upfront.
- Without the cost of the battery and charging infrastructure, the upfront cost of the e-bus is almost the same as a diesel bus while the charging fee is less than the cost of diesel saved. Thus, the bus operator saves from day one.
- Once the utility provider's costs are fully recovered, the bus service provider owns the battery and charging assets.

Example

Enel-Engie (two energy companies) model in Santiago, Chile

How to monitor and evaluate e-bus operations?

Once e-buses are procured and operations begin, **continuous monitoring and evaluation** using a data-driven approach is critical to ensuring best possible use of available resources.

Step 1 Define Key Performance Indicators (KPIs)

Energy cost per km to determine if bus operations are in line with estimates and to compare electric with ICE buses

Energy performance to identify any seasonal variability, and energy efficiency trends by route or operator.

Utilisation of fleet to compare actual usage of e-buses compared to their possible usage. Low utilisation could indicate operational issues.

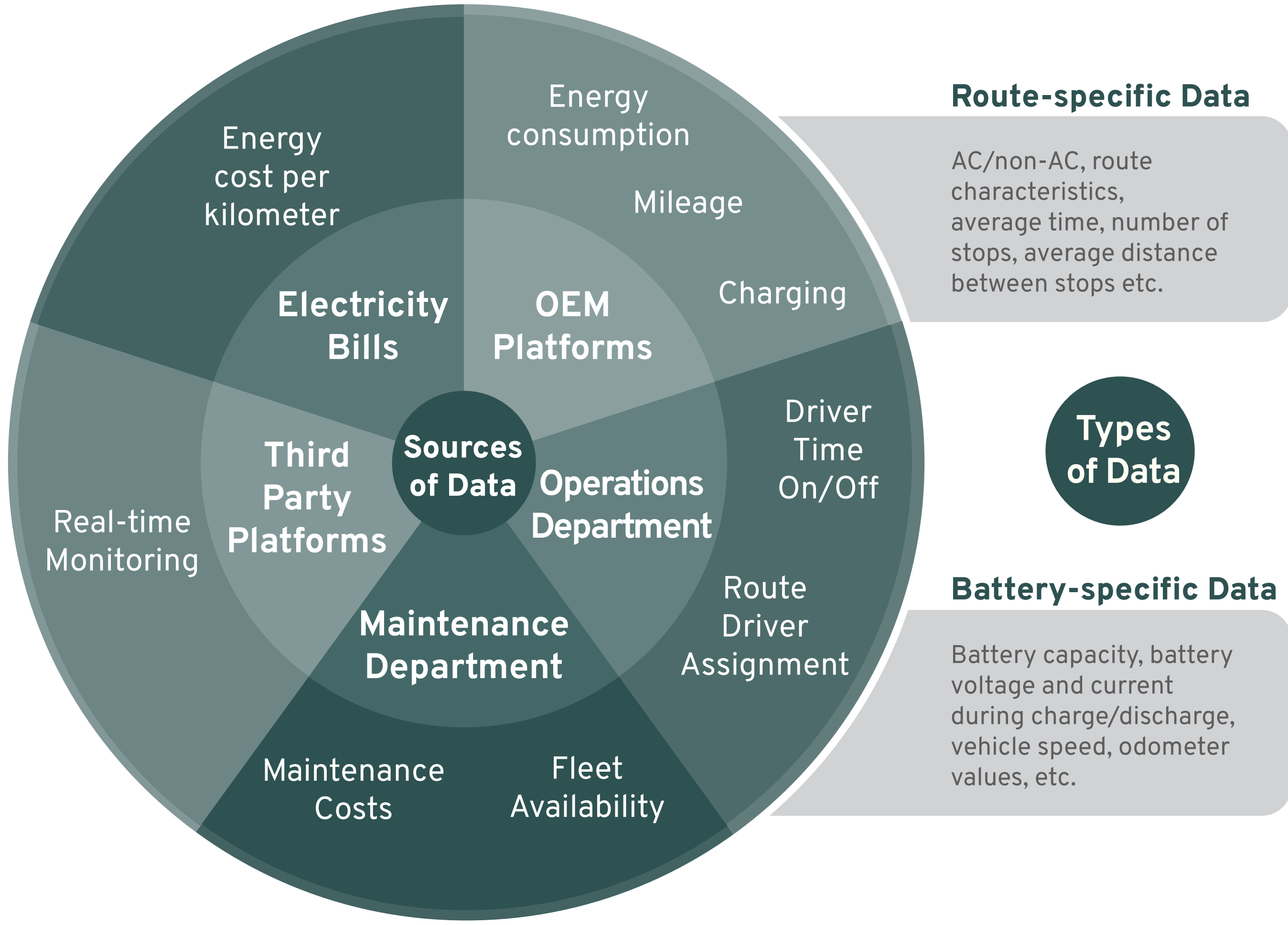
Ongoing lifetime cost analysis to compare actual operations and maintenance costs with projected costs and actual costs of ICE buses.

Emission reduction to estimate diesel consumption and emissions avoided by shifting to e-buses, by comparing with mileage of ICE buses.

Availability of fleet to show how often how often e-buses were put into service, how often buses were recalled, or removed from the service due to any incident.

Step 2 Collect relevant data

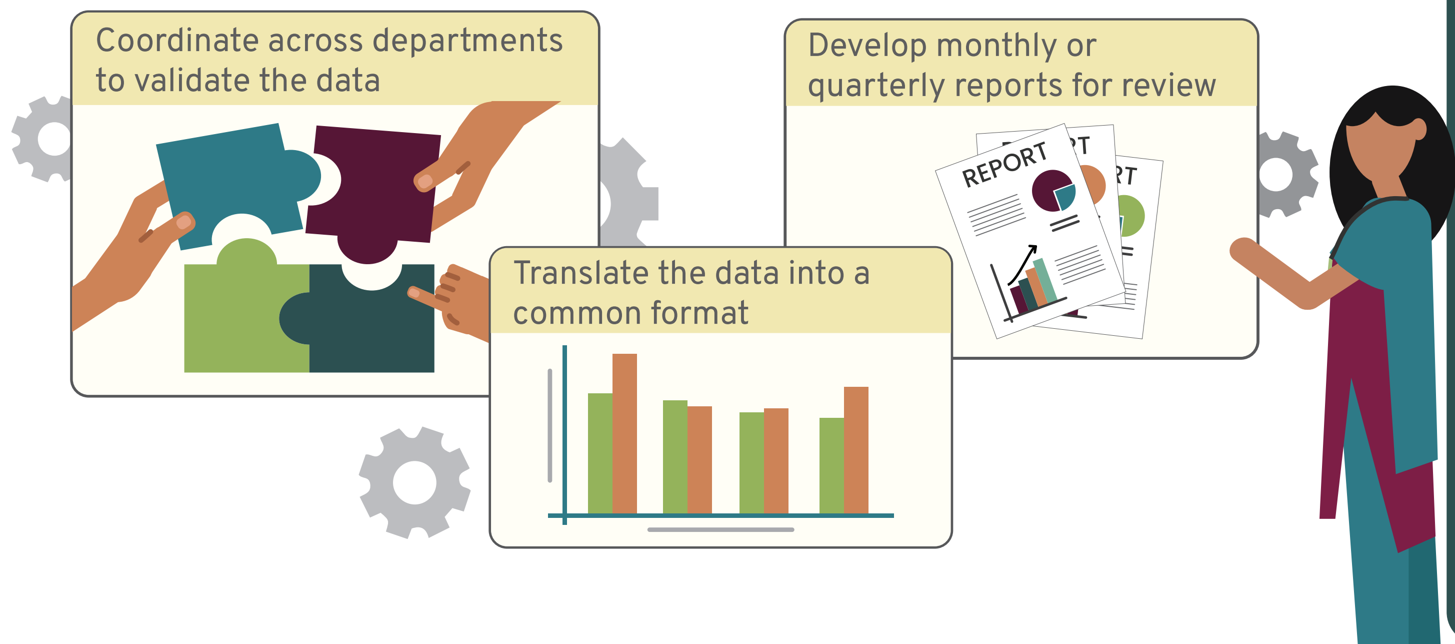
Data needs to be collected from several sources:



Step 3 Analyse the data to assess performance

Analysis can help understand the true costs and benefits of e-bus deployment, inform operational changes to get the most out of e-buses, and inform future needs of the fleet.

Transport agencies should designate a point of contact to maintain and evaluate the collected data.



But are e-buses enough?

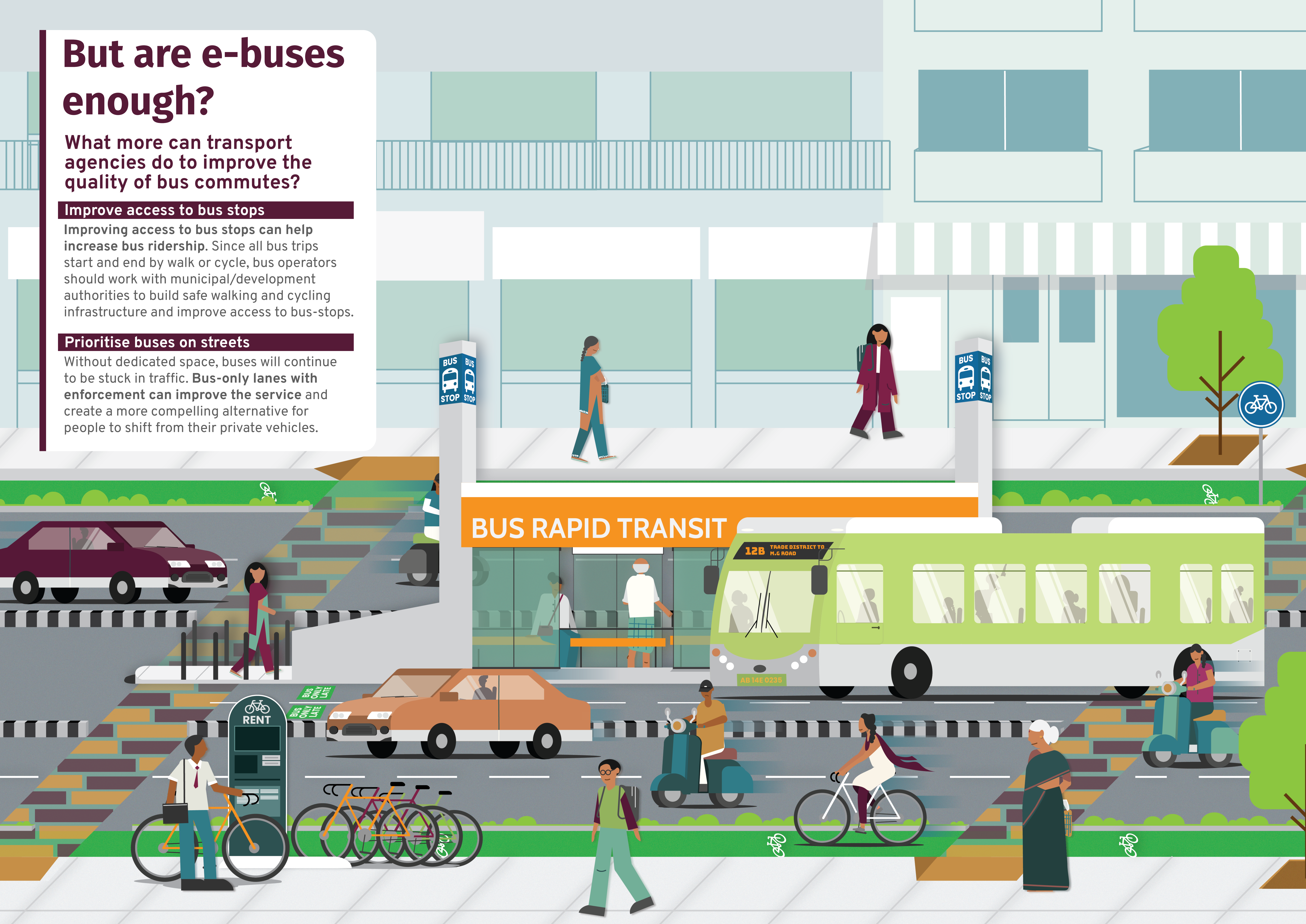
What more can transport agencies do to improve the quality of bus commutes?

Improve access to bus stops

Improving access to bus stops can help increase bus ridership. Since all bus trips start and end by walk or cycle, bus operators should work with municipal/development authorities to build safe walking and cycling infrastructure and improve access to bus-stops.

Prioritise buses on streets

Without dedicated space, buses will continue to be stuck in traffic. **Bus-only lanes with enforcement can improve the service** and create a more compelling alternative for people to shift from their private vehicles.



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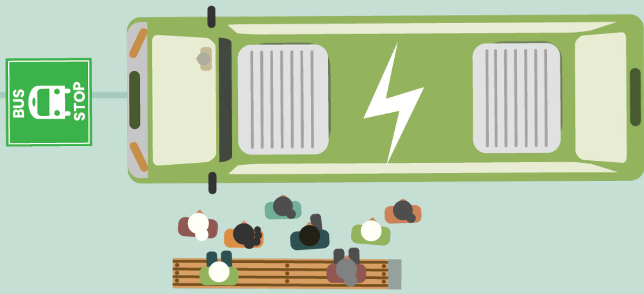
The **Association of State Road Transport Undertakings (ASRTU)** is the apex coordinating body working under the aegis of the Ministry of Road Transport & Highways, Government of India, representing 70 members operating 150,000 buses across India.

The **Institute for Transportation and Development Policy (ITDP)** works with cities worldwide to create healthy and liveable communities through high-quality public transport including e-mobility, safe spaces for walking & cycling, traffic reduction mechanisms, and people-centered policies.



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