Alliance for an Energy Efficient Economy

SHAKTI SUSTAINABLE ENERGY FOUNDATION

CHARGING INDIA'S BUS TRANSPORT

A Guide for Planning Charging Infrastructure for Intra-city Public Bus Fleet

Executive Summary

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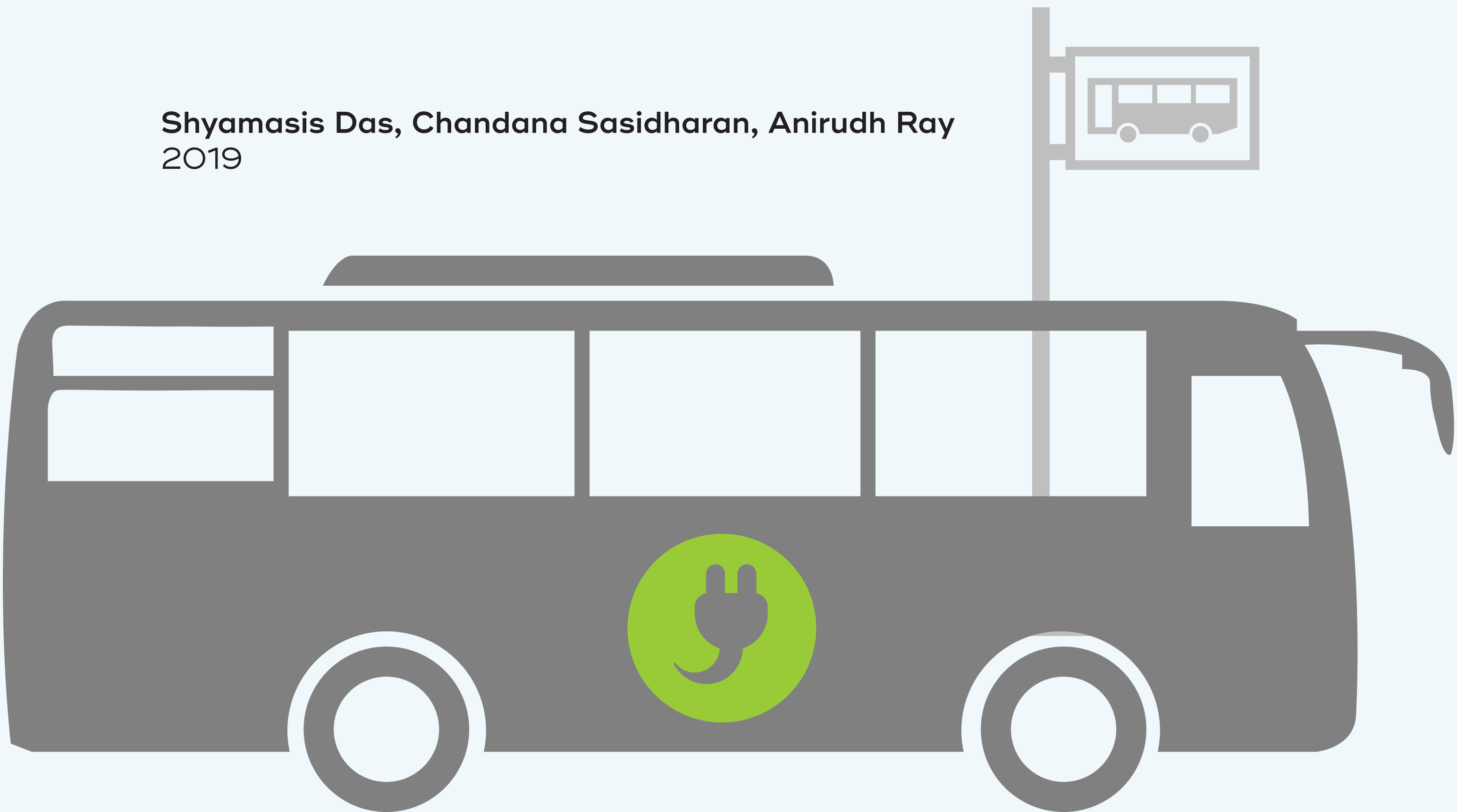
2019



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Shakti Sustainable Energy Foundation seeks to facilitate India's transition to a sustainable energy future by aiding the design and implementation of policies in the following sectors: clean power, energy efficiency, sustainable urban transport, climate policy and clean energy finance.

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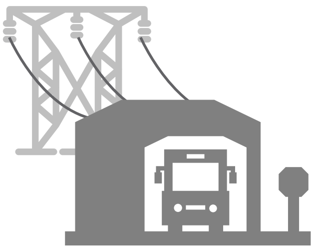
INTRA-CITY PUBLIC FLEETS WAY TO GO FOR ELECTRIFICATION

The Government of India has expressed an ambitious outlook to achieve 100% Electric Vehicle (EV) sales by 2030. This has created much interest and also noise around the electric mobility sector, although concrete initiatives seen on the ground are few. However, the approval of the Phase-II of the FAME (Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles) scheme by the Department of Heavy Industry (DHI) which has a budgeted fund of ₹100 billion has given the sector a much-needed direction and stimulus for implementation. The scheme is found to encourage especially the electrification of the public bus segment.



ELECTRIC MOBILITY IS UNIQUE FROM THE REST OF THE ROAD TRANSPORTATION MODES DUE TO THE FACT THAT ITS IMPLEMENTATION IS INEXTRICABLY LINKED WITH THE ELECTRICITY DISTRIBUTION SECTOR.

Also, from the perspective of the Total Cost of Ownership (TCO)[1], electric technology may be an attractive proposition for a bus service provider in India. Considering the competitive advantages of an e-bus and the less range anxiety as far as intra-city public bus fleet is concerned, switching to electric format merits consideration in the current scheme of things.

The charging infrastructure is the backbone of electric mobility. A substantial volume of investment would be necessary to create the infrastructure for an e-bus fleet. Hence, understanding the charging demand and preferences of a public e-bus fleet is critical to make the investment worthwhile. Moreover, electric mobility is unique from the rest of the road transportation modes due to the fact that its implementation is inextricably linked with the electricity distribution sector. Connection to the required service voltage of the electricity distribution network is an essential requirement for running charging stations. As the public bus fleets in the cities are embarking on the electric journey, there is very little space to make errors as it may adversely impact the public transport system. In order to make a seamless transition to electric mode, it is imperative that the establishment of required charging infrastructure is planned in advance and with enough due diligence. However, currently, the bus service providers are not familiar with the e-bus operation and the charging technologies and do not have the necessary technical and commercial know-how to invest in and manage e-bus fleets, especially to plan and set up charging infrastructure. Also, the OEMs or third-party operators in India are yet to garner sufficient hands-on experience in supporting bus service providers to operate fully electric bus fleets.

Against this backdrop, the study "***Charging India's Bus Transport***" aims to provide definitive guidance to the bus service providers and OEMs in setting up charging infrastructure for an intra-city e-bus fleet in a Tier-I or Tier-II city in India. The study recognises that the success of the e-bus transport depends on several factors such as the technical specifications and the cost of different charging technologies, the available electricity distribution network, the current e-bus specifications, the intra-city bus operation characteristics, and the charging infrastructure space requirement.

1 TCO includes capital and operating costs of a vehicle.

INTRA-CITY BUS ROUTE LENGTHS

Route lengths are a critical factor for planning the establishment of charging infrastructure for an e-bus fleet. When the study assesses the longest and shortest bus routes of the Tier-I and Tier-II Indian cities, it finds that **the root-mean-square (RMS)[2] of the intra-city bus route lengths is about 33 km (in a single trip)**. It would be interesting to see if the range of an e-bus is sufficient to cover the estimated route length.

E-BUS BATTERY CAPACITY AND DRIVING RANGE

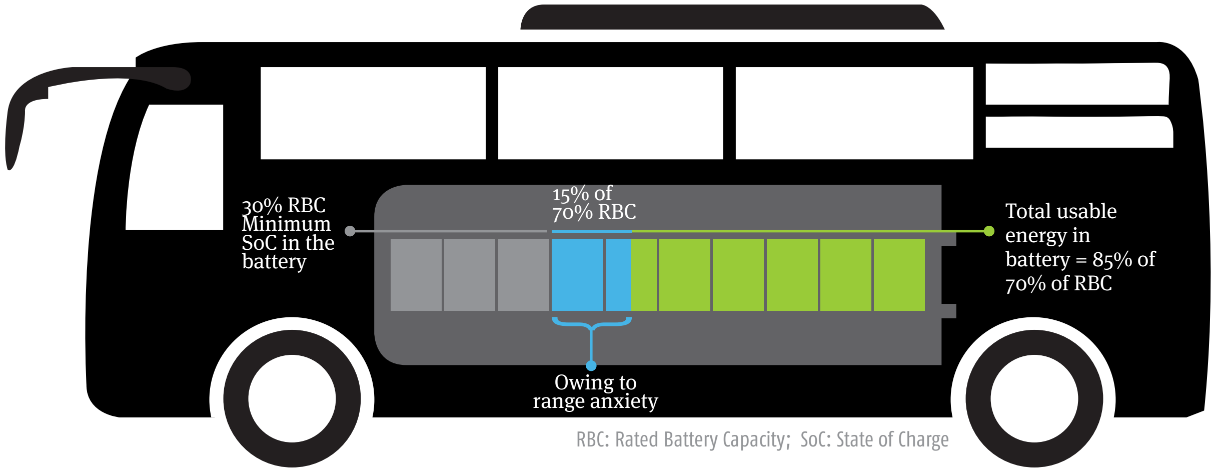
The existing 12-meter e-bus models mostly have battery capacities of 300 kWh which are almost four times more expensive than a comparable diesel bus and nearly ten times costlier than a similar capacity CNG/ LNG bus. Since the cost of a battery accounts almost 50% to 60% of the cost of an e-bus, the study in its bid to explore the possibility of adopting a lower battery capacity for an intra-city e-bus fleet, analyses two battery capacities - 100 kWh and 200 kWh, which are the other battery options for e-buses currently.

FOR A BATTERY RATED 100 KWH, USABLE ENERGY IS ESTIMATED TO BE 59.5 KWH WHEREAS IT IS 119 KWH FOR A BATTERY RATED 200 KWH

Whether the lower battery capacities would be appropriate for the bus fleet, one has to examine the assured range offered by the battery capacities. This warrants an understanding of the performance characteristics of a typical battery. To start with, **one should bear in mind that the rated battery capacity, which is the total amount of energy that the battery contains, in practice does not correspond to the total energy available for usage**; the primary reason being the limit up to which a battery can discharge *i.e.*, the maximum depth of discharge (DoD). This is to maintain the health of the battery. Going by the thumb rule for lithium iron phosphate ($LiFePO_4$) batteries (commonly called LFP batteries), the maximum DoD is considered to be 70% which implies that 30% of a battery's rated energy capacity is non-usable. It is worthwhile to mention here that this 70% of the rated battery capacity (RBC) is displayed as 100% on the display panels of the EVs and is called the displayed battery capacity.

Of the available 70%, it is recommended that the battery of an e-bus should never be discharged below 15% to avoid any possibility of getting stranded. This implies that for the 100 kWh and 200 kWh battery capacities, the total energy that would practically be available for running an e-bus would be 70 kWh (*i.e.*, 70% of 100 kWh) and 140 kWh (*i.e.*, 70% of 200 kWh) respectively. Of the 70% energy that is available in both capacities of batteries, 15% has to be reserved as the minimum energy (charge) left in a battery when an e-bus arrives at a charging station to avoid range anxiety. Therefore, the usable energy in a battery with rated capacity ***x*** kWh is (70 – (70*15%))% * ***x*** kWh *i.e.*, 59.5% * ***x*** kWh (Figure ES 1). Thus, **for a battery rated 100 kWh, usable energy is estimated to be 59.5 kWh whereas it is 119 kWh for a battery rated 200 kWh.**

2 The RMS distance has been considered as the best indicator of the central value for the data available on route lengths of the aforementioned cities, because if the data have a significant number of outliers, the calculation of the average of the route lengths will lead to a skewed and possibly a lower value.



ES 1: ENERGY CHARACTERISTICS OF AN EV BATTERY

A 200-KWH BATTERY POWERED E-BUS WOULD OFFER A DRIVING RANGE BETWEEN 59.5 KM AND 148.8 KM

What do these derived usable energy values mean? One can estimate the corresponding driving ranges of an e-bus against the given rated battery capacities. From the mileage data of the existing e-bus models, the study finds that the maximum and the minimum values for energy consumption per km are 2 kWh and 0.83 kWh respectively which, in turn, indicate that **a battery rated 100 kWh would allow an e-bus to travel a maximum distance of 74.4 km and a minimum distance of 29.8 km**. On the other hand, **a 200-kWh battery powered e-bus would offer a driving range between 59.5 km and 148.8 km**.

Given the RMS of bus route lengths in the Tier-I and Tier-II cities is about 33 km, **the study infers that a 200-kWh rated battery is most suited for a 12-m e-bus intra-city fleet in India** and the corresponding driving range is about **59.5 km** (conservative estimate).

POSSIBILITIES OF BUS CHARGING

To plan charging infrastructure for an e-bus fleet, it is imperative to take into account the following questions:

- Where to charge *i.e.*, at the depots (nodes) and/ or en-route
- When to charge *i.e.*, overnight and/ or during operating hours

To answer the first query *i.e.*, where the siting of a charging station for an e-bus fleet should be, the following factors are important.

- Ease of setting up the charging station
- Maintaining the service frequency of a bus fleet
- Supporting the range of an e-bus on a route

Considering these factors, the origin and destination nodes (depots or terminals) could be the potential primary sites for setting up charging stations for an e-bus fleet on a route. The bus service provider could also consider en-route charging at an intermediate charging station (between origin and destination nodes) to replenish the bus fleet with sufficient charge to reach the destination node if a case arises where the range of the bus may not be adequate to make the trip. However, in such a case, because of charging time, the duration of the halt would get more prolonged than usual, and this would negatively affect the service frequency of the route. Hence, an intermediate

IT IS NOT NECESSARY TO SET UP INTERMEDIATE/ EN-ROUTE CHARGING STATIONS

charging station should only be considered when the range of the e-bus is not sufficient to cover the entire route length.

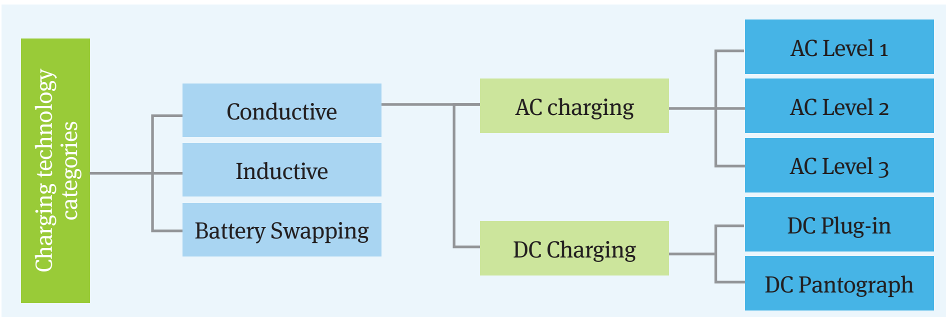
As the estimated minimum possible driving range of an e-bus is about 59.5 km which is greater than the RMS route length (33 km) by a comfortable margin, the e-bus would be able to complete a trip successfully without requiring a charge en-route. **As any need to charge an intra-city e-bus fleet between the origin and destination nodes is not envisaged, it is not necessary to set up intermediate/ en-route charging stations.**

Thus, the bus charging will happen at the depots which can be attended post-completion of trips during the operating hours of the bus transport network or overnight when the bus transport pauses for hours. The role of overnight charging is to reduce the requirement for charging during operational hours of the bus fleet and thus, to ensure that the charging time does not negatively affect the service frequency of the concerned route.

The identified charging possibilities set the stage for the selection of best-fit charging technology for e-buses among the available options in the market.

ELECTRIC BUS CHARGING TECHNOLOGIES

Charging technologies currently deployed worldwide for charging e-buses are diverse in their method of electricity transfer, power output levels, control and communication capabilities, *etc*. The lack of international standards for these charging technologies makes it difficult to compare the different charging technologies available in the market in a consistent way and make an appropriate decision to select a suitable charging option for e-buses. To objectively assess the range of charging options in the context of e-bus charging, the study creates a framework (Figure ES 2) to classify and characterise them based on certain salient features such as their method of electricity transfer, power output levels, *etc*.



ES 2: CATEGORIES OF CHARGING TECHNOLOGIES

However, all these types of charging technologies may not be the plausible options for charging e-buses. To identify the ones which could be practically employed for charging e-buses in India, the study undertakes a thorough comparative assessment of the charging mentioned above options using a set of critical parameters. Following are the major findings from the examination.

- **AC-I technology requires a service voltage which is not prevalent in India.**
- **There is no confirmed case of AC-II charging of e-bus globally at India's power level (<7.4kW).**

- **Adoption of battery swapping technology for e-buses is found at a pilot scale. The complexity of the operation of the technology, high cost of installation and operation and the requirement for significant modification of the bus design are some of the significant hurdles in its implementation.**
- **Inductive charging is not preferred due to the complex nature of the system, high cost of installation, the necessity for modification of roads and low efficiency in energy transfer.**

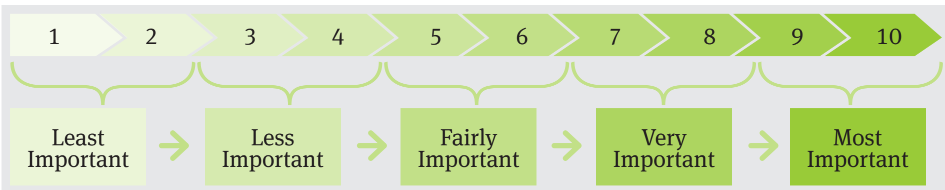
Based on the analysis, **the study shortlists AC-III and DC charging as the plausible charging options. The latter has two sub-classes depending on the EVSE design – Pantograph and Plug-in**. These are further examined to select the best-fit against a charging requirement of an intra-city e-bus fleet.

THE STUDY SHORTLISTS AC-III AND DC CHARGING AS THE PLAUSIBLE CHARGING OPTIONS. THE LATTER HAS TWO SUB-CLASSES DEPENDING ON THE EVSE DESIGN – PANTOGRAPH AND PLUG-IN

SELECTION OF "BEST FIT" CHARGING TECHNOLOGY – APPLICATION OF MULTI-CRITERIA DECISION MATRICES

The effectiveness and feasibility of deployment and use of a charging technology hinge on a range of factors, both technical and economic. On the one hand, the technology should satisfy the criteria for charging the vehicle (*e.g.*, charging time, grid infrastructure required, *etc.*) and on the other hand, its establishment and operation should be cost-effective. Considering that charging technologies are still evolving, the selection of a suitable charging technology may involve certain trade-offs.

Recognising the possible complexity to identify the best-fit technology, the study develops composite Multi-Criteria Decision Matrices (MCDMs), consisting of a set of techno-economic parameters where each parameter is assigned a weight based on the assessed degree of importance using the following scale (Figure ES 3).



ES 3: SCALE FOR ASSESSING THE IMPORTANCE OF A PARAMETER

The set of technical and economic parameters considered in the composite MCDMs and their assigned weights may vary with charging possibilities as the criteria to evaluate "*best-fit*" also change. Each charging technology is ranked against individual parameters whereby the technology which satisfies most the ideal value for a parameter is ranked highest. Thus, one arrives at a normalised weighted rank for a technology. The charging technology which notches up the highest normalised weighted rank qualifies as the most preferred option.

Considering the two charging possibilities for a bus fleet, *i.e.*, depot charging post-completion of trips and depot charging overnight, this investigation constructs two separate MCDMs (Table ES 4 and Table ES 5) which have differing weights for the set of technical and economic parameters.

AC-III EVSE EMERGES AS THE MOST SUITABLE OPTION FOR CHARGING E-BUSES DURING OPERATING HOURS POST COMPLETION OF TRIPS AS WELL AS OVERNIGHT.

ES 4: MULTI-CRITERIA DECISION MATRIX FOR SELECTION OF CHARGING TECHNOLOGY FOR CHARGING OF E-BUSES DURING OPERATING HOURS

Parameters	Criteria	Weight (W)	AC III		DCFC			
					Pantograph		Plug-in	
			R_{AC-III}	$W*R_{AC-III}$	R_{DCP}	$W*R_{DCP}$	R_{DCC}	$W*R_{DCC}$
Technical Parameters	Charging time	10	2	**20**	3	**30**	2	**20**
	Effectiveness to maintain service headway of a bus route	10	2	**20**	3	**30**	2	**20**
	Grid voltage required	6	3	**18**	1	**6**	3	**18**
	Area required per EVSE (including allied infrastructure)	4	3	**12**	1	**4**	2	**8**
Economic Parameters	Capital cost per EVSE	10	3	**30**	1	**10**	2	**20**
	Cost of electricity for charging a bus by an EVSE	10	3	**30**	1	**10**	3	**30**
	Cost of ancillary infrastructure	5	3	**15**	1	**5**	3	**15**
	Maintenance cost per EVSE	2	3	**6**	1	**2**	2	**4**
	Sum	**57**	**151**		**97**		**135**	
	Normalised Weighted Ranks		**2.65**		**1.70**		**2.37**	

ES 5: MULTI-CRITERIA DECISION MATRIX FOR SELECTION OF CHARGING TECHNOLOGY FOR CHARGING OF E-BUSES OVERNIGHT

Parameters	Criteria	Weight (W)	AC-III		DC			
					Pantograph		Plug-in	
			R_{AC-III}	$W*R_{AC-III}$	R_{DCP}	$W*R_{DCP}$	R_{DCC}	$W*R_{DCC}$
Technical Parameters	Grid voltage required	6	3	**18**	1	**6**	3	**18**
	Charging time	4	2	**8**	3	**12**	2	**8**
	Effectiveness to maintain service headway of a bus route	4	2	**8**	3	**12**	2	**8**
	Area required per EVSE (including allied infrastructure)	4	3	**12**	1	**4**	2	**8**
Economic Parameters	Capital cost per EVSE	10	3	**30**	1	**10**	2	**20**
	Cost of electricity for charging a bus by an EVSE	10	3	**30**	1	**10**	3	**30**
	Cost of ancillary infrastructure	5	3	**15**	1	**5**	3	**15**
	Maintenance cost per EVSE	2	3	**6**	1	**2**	2	**4**
-	Sum	**45**	**127**		**61**		**111**	
	Normalised Weighted Ranks		**2.82**		**1.36**		**2.47**	

W = Weight of a criterion for a particular charging requirement of a specific vehicle segment

R = Rank of a charging technology against a particular criterion

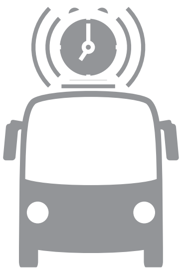
The charging technology which notches up the highest normalised weighted rank would qualify as the most preferred option. The least normalised weighted rank would determine the least preferred option.

As indicated by the MCDMs, **AC-III EVSE emerges as the most suitable option for charging e-buses during operating hours post completion of trips as well as overnight. However, one should be mindful of the fact that AC charging is only possible when the vehicle has an on-board charger of suitable capacity.**

One should also consider the outcome of the MCDMs with some caution. The EV market in India and globally is still at a nascent stage and the vehicle/ battery-features as well as charging technologies are evolving quite rapidly which may impact the technical and economic viability of the concerned charging technologies in the coming months. Therefore, it is critical to bear in mind that the given rankings of the charging options are reflective of the present scenario only and may change in the future as the EV market matures. It is essential that the stakeholders take a fresh look at Decision Matrices and revise them after a period to make appropriate decisions.

FRAMEWORK FOR EVALUATION OF REQUIRED CHARGING CAPACITY AT A DEPOT

To assess the requisite charging capacity at a depot, *i.e.*, the number of AC-III EVSEs to be deployed at a depot for a route, the study proposes a framework in the form of a set of relations involving some critical operational parameters. In developing the framework, the study sets some important objectives to accomplish.



EVEN POST-ELECTRIFICATION, IT IS VITAL TO MAINTAIN THE SERVICE FREQUENCY OF A ROUTE AT PAR WITH THE BASELINE

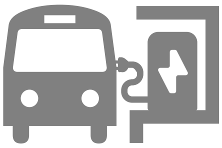
- **To achieve maximum possible utilisation of the installed EVSEs serving the charging demand of the route at the depot** (optimal average Capacity Utilisation Factor (CUF) of the EVSEs serving a route is assumed to be 85%)
- **To maintain the service frequency of the route at par with the baseline**
- **To charge an e-bus only when it cannot undertake another full trip on the remaining battery charge**
- **To replace the existing ICE buses on a route with an equal number of e-buses *i.e.*, the fleet size remains the same**

The hallmark of the framework is the formulated relations take into consideration the critical operational parameters which potentially impact the effectiveness of the intra-city bus service on a route post electrification. The parameters include the time headway[3] of a route operating from the concerned depot (h_n, in minutes) and the time headway of the route (served by the same depot) with highest service frequency (h_{min}), the length of the route from origin depot to destination depot (d, in kilometers), the number of trips completed by the e-bus before charging is required (n)[4], the effective charging time for an e-bus (t_c, in minutes)[5], and the ratio of the total time designated for charging e-buses in a day to total daily operating hours of the bus network (r)[6].

The study finds that the energy requirement of the e-bus at the time of charging is equal to $n(d+\Delta)2$ kWh, where 2 represents the fuel economy of the e-bus in kWh/km and represents a friction factor[7] of the route, due to which the e-bus may lose some additional energy which is assumed to be 10% of the energy required to complete one trip.

3 Time headway is the inverse of the service frequency.
4 It can be calculated by dividing the driving range of the e-bus by the route length.
5 An e-bus may be left with some energy in the battery every time it reaches a depot.
6 The ratio directly impacts the number of EVSEs required for charging e-buses on a route.
7 In urban transport, a particular 'friction factor' is attributed to a route, which is a result of the time lost in traveling due to forced delays, poor road (network) quality, barriers, congestion, etc. It is different at different times during the day and is the highest during the peak hours.

Hence, the effective charging time (t_c) for an AC-III EVSE which is envisaged to depend on the energy requirement of the e-bus, the output power and the CUF of the EVSE and the ratio of time designated for charging to operating hours, is found to be equal to $\frac{n\times(d+\Delta)\times 2}{80\times r\times 0.85}\times 60.$



THE RELATIONS BETWEEN TIME HEADWAY ON A ROUTE AND THE EFFECTIVE CHARGING TIME OF AN E-BUS DETERMINE THE REQUIRED CHARGING CAPACITY AT A DEPOT.

Whether the time headway on a route is greater or less than the effective charging time of an e-bus is the most critical aspect that needs to be considered to evaluate the required charging capacity at a depot. Hence, two separate cases have been studied in this regard.

In the first case, the study considers that the time headway on the most frequent route is greater than/ equal to effective charging time for an e-bus *i.e.*, $h_{min}\geq t_c$. In this case, an EVSE per bus route would be enough to serve the charging demand of the route at the depot. The study recommends that an attempt should be made to explore the possibility of sharing of a charger amongst multiple routes provided its idle time is enough.

In the other case, the time headway on the route is considered to be less than the effective charging time for an e-bus *i.e.*, $h_n<t_c$. Meticulous planning would be necessary to schedule the charging activities at the depot post completion of trips during operating hours as the charging time could easily disrupt the route headway.

To evaluate the required number of EVSEs at a depot to serve the route, the study understands that $\frac{t_c}{h_n}=k$ where $k>1$, and]k[number of EVSEs per route should be deployed[8]. For all the other routes operating from the same depot, a similar analysis has to be carried out. It is possible that the analysis may yield different and values for individual routes.

The study also infers that the devised relations (as explained above) can be employed in two operational scenarios – one, where the designated time for bus charging is same as the network's operating hours (there is no overnight charging which, thus, does away with any manpower requirement at night), and in the second scenario, the designated time for charging e-buses spans a full day, *i.e.*, 24 hours (this considers overnight charging which reduces the requirement for charging during operational hours).

BEYOND CHARGING CAPACITY PLANNING

Setting up charging infrastructure for a public bus fleet is a multi-dimensional challenge. While the objective to satisfy the mobility demand should be at the core of the infrastructure planning exercise, it is critical to consider other elements. The aspects of EV charger specifications and corresponding electricity grid connection and ancillary infrastructure requirements, cost of installation and necessary spatial provision are some of the vital pieces of the planning puzzle. Not to mention, to crack this, it would require an understanding of a range of issues and involvement of a number of actors. To provide some useful guides to establish charging infrastructure at a depot, the study comes out with a Reference Sheet (Table ES 6) on charging station. The Reference Sheet takes into account the identified "*best-fit*" charging technologies which is AC III charger and other key results of this research.

8]k[is the least integer greater than or equal to k.

ES 6: REFERENCE SHEET FOR AC III CHARGER

Aspects	Parameters	Data for AC – III
Charger specifications	Input voltage to EVSE (V)	415
	Maximum output power from EVSE (kW)	80
	Charging time for buses (battery rated 200 kWh)	1.5-2 hours [a]
Grid connection requirement	Electricity connection required (HT/ LT)	HT
	Ancillary infrastructure required	Distribution Transformer
		HT/ LT Switchgear
		Cables
		Protection relay
		SCADA
	No. of chargers that can be supplied from a 1 MVA transformer	10
Cost Estimates	Capital cost of charging technology (₹)	3,50,000 – 6,40,000
	Cost of ancillary infrastructure (₹)	2,50,000 – 4,00,000
	Cost of electricity for charging (energy and demand charge as per connection)	Energy charge and demand charge as per HT (415V)
	Maintenance cost (%)	10% of installation cost as periodic maintenance
		2% of installation cost as regular maintenance
Charging facility space requirements (for a 12m e-bus)	Parking Bay Type	Angular
	Parking Bay Area (m^2)	39
	Parking Bay Angle (°)	45
	Maintenance Bay Type	Sawtooth
	Maintenance Bay Area (m^2)	36
	Maintenance Bay Entry Angle (°)	15
	Maintenance Bay Exit Angle (°)	30
	Marking specifications	Dashed lines at entry/ exit of station
		Solid lines between bays for non-negotiable movement
	Area required for EVSE (m^2)	0.8
	Area required for ESS (m^2)	80 [9]
	Area required for 3-phase pole mounted DT (m^2)	9
	Covered waiting area (per fully occupied 40-seater bus) (m^2)	30 [10]
	Minimum Entry/ Exit Lane Widths (m)	8
	Parking Area Lane Widths (m)	7.5 [b]
	Inner Turning Radius (Path Traced by the Inside Front Wheel) (m)	6.5 [b]
	Outer Turning Radius (To Clear the Outside Rear Overhang) (m)	13.2 [b]
	Area of Enquiry, Pass and Ticket Counter (m^2)	42
	Area Required for Ancillary Infrastructure (m^2)	600
	Area of Administration and Operation Office (m^2)	600
	Area of Depot Office (m^2)	600
	Area of Canteen (m^2)	80
	Area of Washroom (m^2)	20
	Area of Maintenance Room and Repair Workshop (m^2)	322
	Gradient of Sub-Level Parking Ramp (%)	10 [b]
	Total Depot Area (Ha)	5.89
	Plot Frontage (m)	423
	Curb Type	Barrier
	Curb Height (cm)	30 [b]
	Bus Stop Area (m^2)	10
	Empty Bay Indicators	Optic
	Canopy Area (m^2)	6430

[a] Refer Appendix A– charging time estimation for details

[b] C. S. Papacostas and P. O. Prevedouros 'Transportation Engineering & Planning', PHI, New Delhi

9 Master Plan Delhi – Modification 2021 (modified till 31/03/2016), Delhi Development Authority

10 Best Practice Guidelines – Airport Service Levels Agreement Framework, International Air Transport Association (IATA) Airport Development Reference Manual, IATA-ACI (Airports Council International)

The study also develops a Roles and Responsibilities (R&R) Matrix (Table ES 7) which highlights the kind of engagement of respective stakeholders required in the charging infrastructure planning exercise. This, however, does not take into account a particular implementation or business model adopted by a bus service provider.

ES 7: ROLES & RESPONSIBILITIES MATRIX REGARDING CHARGING INFRASTRUCTURE PLANNING

Key activities in charging infrastructure planning	Bus service provider	Bus OEM	Charging technology supplier	DISCOM
Understanding intra-city public bus network characteristics in the context of e-bus roll-out	P	S		
Examining the requisite e-bus size, battery capacity, driving range for a route	P			
Identifying suitable sites for siting charging stations for a route	P		S	
Understanding the specifications of different charging technologies	P	S		S
Examining the capex and opex for different charging technologies	P			
Evaluating the charging technologies using MCDMs and selection of best-fit charging option	P			S
Assessing the relation between time headway and e-bus charging time	P		S	
Examining the optimum charging capacity to be deployed for a route	P		S	
Assessing the necessary grid connection	S		S	P
Evaluating the charging facility space requirements	P		S	

P: Primary responsibility; S: Secondary responsibility

From the R&R Matrix, it is quite evident that a bus service provider would have the primary responsibility to attend the bulk of the identified preparatory activities to set up the charging infrastructure for their e-bus fleet. However, undertaking these activities could be challenging to a bus service provider since this is a new template for them and they may not have the necessary experience and knowledge. Support from external experts or agencies would be beneficial for the bus service provider to effectively carrying out the planning. Not to mention the importance of the roles of other stakeholders, namely the bus OEMs, the charging technology suppliers and the DISCOMs in developing the plan for rolling out charging infrastructure for e-bus fleets. The fact that the success of the bus electrification initiative hinges on the close coordination among the stakeholders cannot be overstated.

QR code for Full Report