

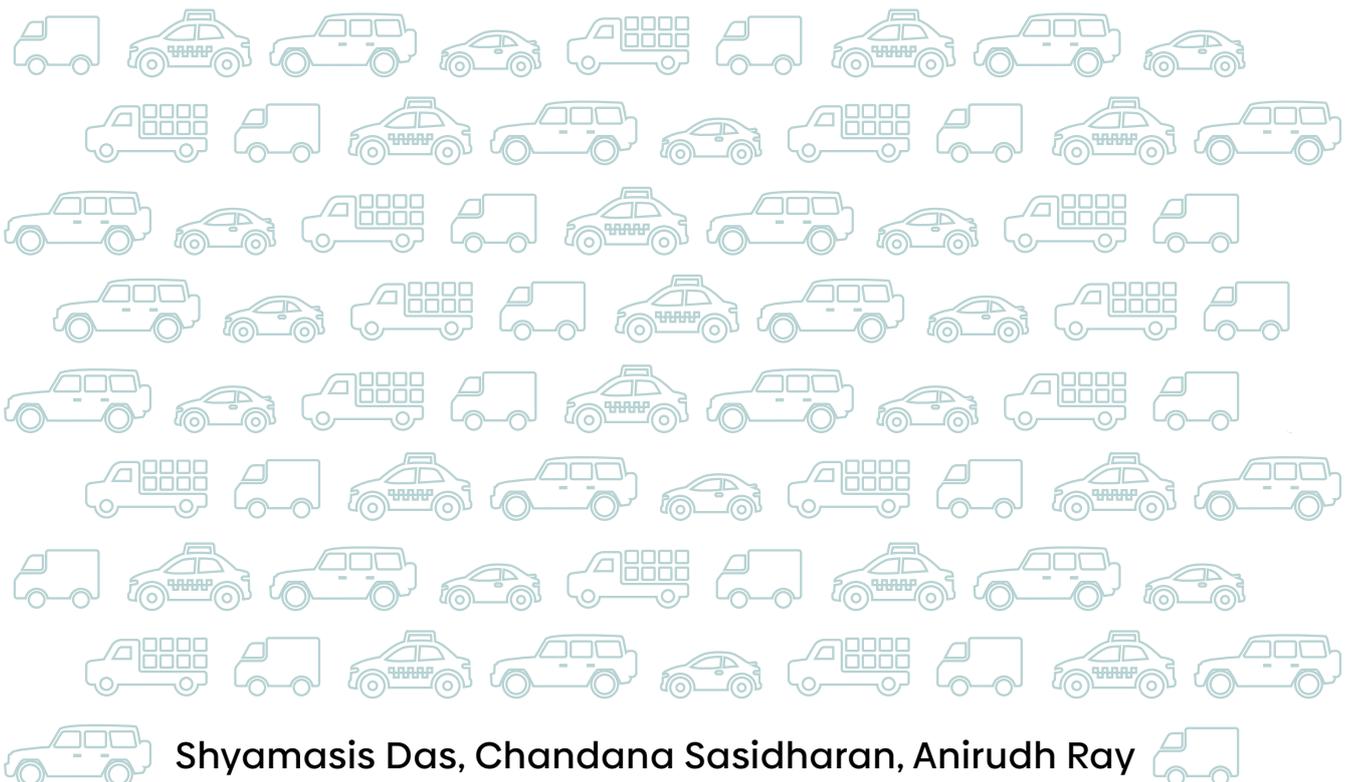
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CHARGING INDIA'S FOUR-WHEELER TRANSPORT

A Guide for Planning Public Charging
Infrastructure for the Four-Wheeler
Fleet in Indian Cities

Executive Summary



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Executive Summary: CHARGING INDIA'S FOUR-WHEELER TRANSPORT –
A Guide for Planning Public Charging Infrastructure for the Four-Wheeler
Fleet in Indian Cities

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Imperative to address charging infrastructure woes of four-wheelers

The electric mobility (e-mobility) sector in India is at a nascent stage. One significant challenge with regard to scaling up electric vehicle (EV) adoption in the country is the lack of provision of EV charging infrastructure to avoid range anxiety. The electric four-wheeler (e-4W) segment in particular needs to tackle this barrier. The central and state governments are encouraging Public Sector Undertakings (PSUs), Power Distribution Utilities, and other public agencies, including Urban Local Bodies (ULBs) and Urban/ Area Development Authorities, to support the establishment of public charging facilities. However, EV charging is a new domain for them, and, thus, several challenges remain with respect to the planning and establishment of e-4W charging infrastructure.



INDIA'S INFRASTRUCTURAL CHALLENGES ARE UNIQUE, AND, HENCE, THE BEST PRACTICES IN E-MOBILITY IDENTIFIED IN ADVANCED INTERNATIONAL MARKETS MAY NOT BE FEASIBLE OR EFFECTIVE TO ADDRESS INDIA'S PROBLEMS

India's infrastructural challenges are unique, and, hence, the best practices in e-mobility identified in advanced international markets may not be feasible or effective to address India's problems; the approach to tackling the challenges and developing solutions needs to be home-grown or tailor-made for Indian cities.

Commercial fleet – a major charging demand

The share of four-wheeler (4-W) commercial fleet in both passenger and goods transport in Indian cities is increasing rapidly. Because of lower per kilometre running cost of an EV as compared to an ICE-vehicle, there is a clear business case for adoption of EVs in commercial 4-W fleet. Hence, 4-W commercial fleets are considered to be a potential target segment for electrification. There is going to be significant charging demand from e-4W commercial fleets, and, consequently, the upcoming public charging facilities need to cater to these fleets to an appreciable extent, in addition to private electric cars. It is anticipated that the bulk of private e-4W charging would be in the form of home charging. Because a commercial 4-W covers more kilometres per day than a private vehicle, the requirement for charging would be higher in the case of the former.

Successful deployment of public e-4W charging infrastructure depends on a set of intertwined factors, including:

- **Capacity utilisation of the charging facilities**
- **Cost recovery by the charging service providers**
- **Cost-effective establishment and operation of the charging facilities**
- **Charging facility accessibility**

To achieve the optimum of these factors, careful planning of charging infrastructure is critical and should take into account two key elements:

- Where to charge, i.e. at captive charging facilities, public parking spaces, or en-route
- How to charge, i.e. the type of charging technology to be adopted

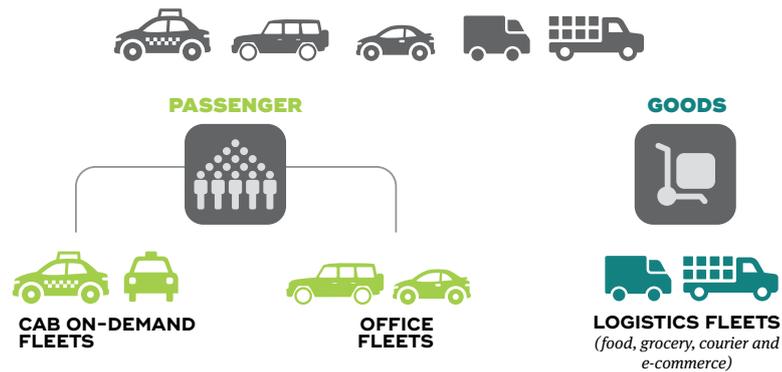
One-size-fits-all approach not the way

The operation of commercial 4-W fleet varies significantly based on the purpose of use/ mobility, origin and destination points of the trips, trip attraction/ generation models, service/ business catchment area, etc. Upon careful scrutiny of the different kinds of operations, these fleets can be broadly segmented into two categories based on the type of load they carry, i.e. passengers or goods. Each of these broad categories is further segmented, as shown in Figure ES 1.



ELECTRIC FLEET SEGMENTS WOULD DEPEND ON A HOST OF CHARGING FACILITIES, WHICH WOULD DIFFER PRIMARILY BASED ON THE LOCATIONAL ASPECT.

E-4W COMMERCIAL FLEETS



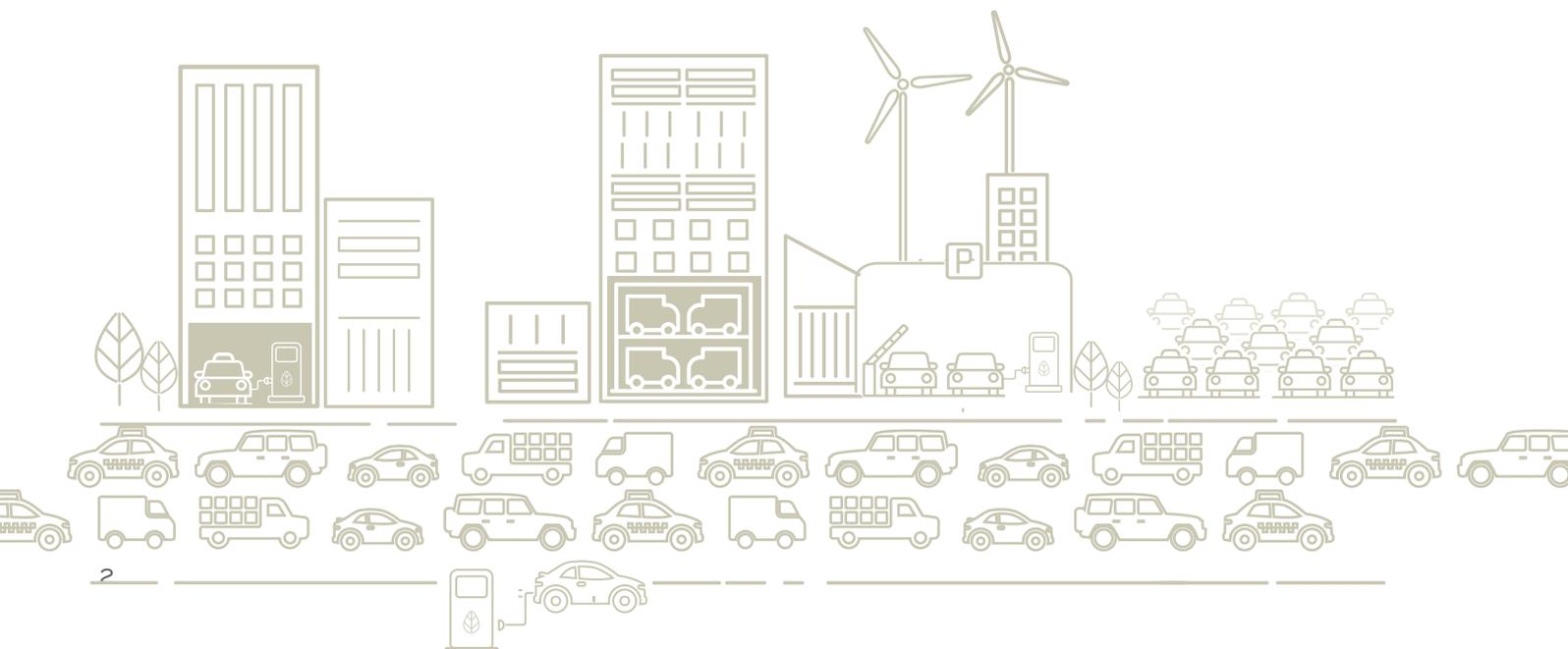
ES 1: DIFFERENT SEGMENTS OF FOUR-WHEELER COMMERCIAL FLEET

It is envisaged that each of the identified electric fleet segments would depend on a host of charging facilities, which would differ primarily based on the locational aspect.

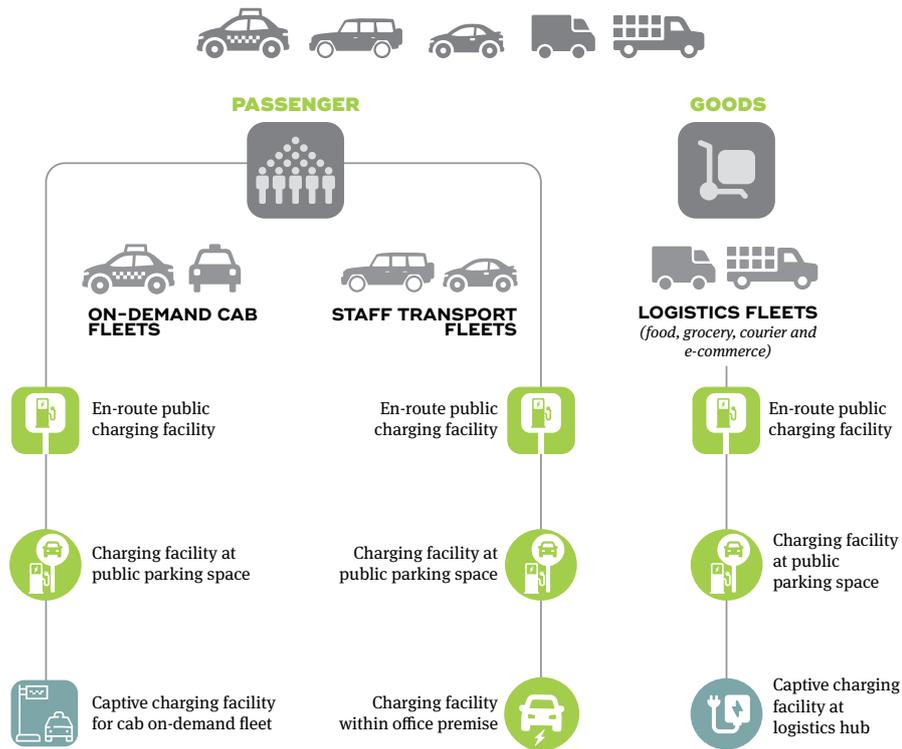
Figure ES 2 highlights the possible types of charging facilities for different e-4W segments. Most of these charging facilities would also fulfil the charging requirements of private vehicles. As the study aims to facilitate the deployment of public charging facilities, it does not examine the captive charging requirements. The following **three** types of **public** charging facilities may be required in order to support e-4W mobility in Indian cities:

1. En-route public charging facilities
2. Charging facilities within office premises
3. Charging facilities at public parking spaces

Public parking space, in turn, are of two types – off-street and on-street.



E-4W COMMERCIAL FLEETS



ES 2: POSSIBLE CHARGING FACILITIES FOR DIFFERENT COMMERCIAL ELECTRIC FOUR-WHEELER SEGMENTS



CRUCIAL FOR THE CHARGING BUSINESS TO APPRECIATE THE PREFERENCE OF E-4W FLEET OPERATORS.

Preference of fleet operators

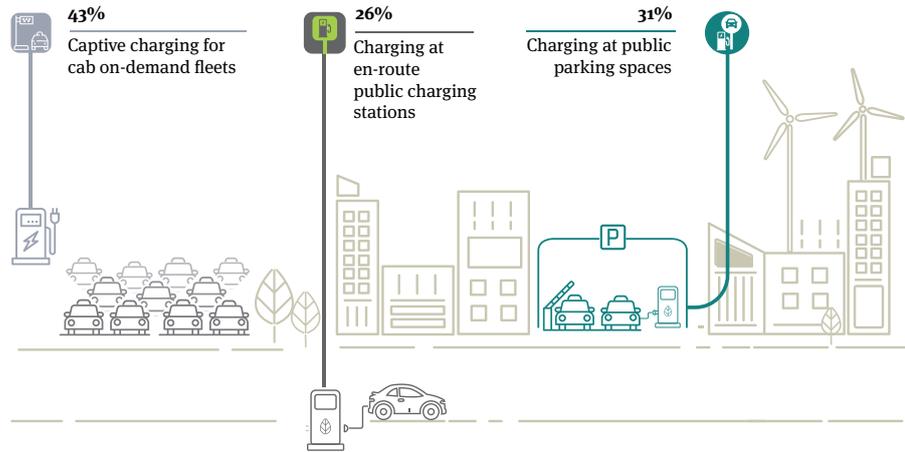
Understanding the customer-choice is critical for any business. It is, therefore, crucial for the charging business to appreciate the preference of e-4W fleet operators. A stated preference survey with the latter confirms or demystifies this important aspect.

The survey results (Figure ES 3) reveal that on-demand cab fleet may prefer captive charging facilities designated for them over other public charging options. However, to avoid range anxiety, an on-demand cab fleet would require intermediate or opportunity charging, for which it would have to use charging facilities at public parking lots and en-route public charging stations.

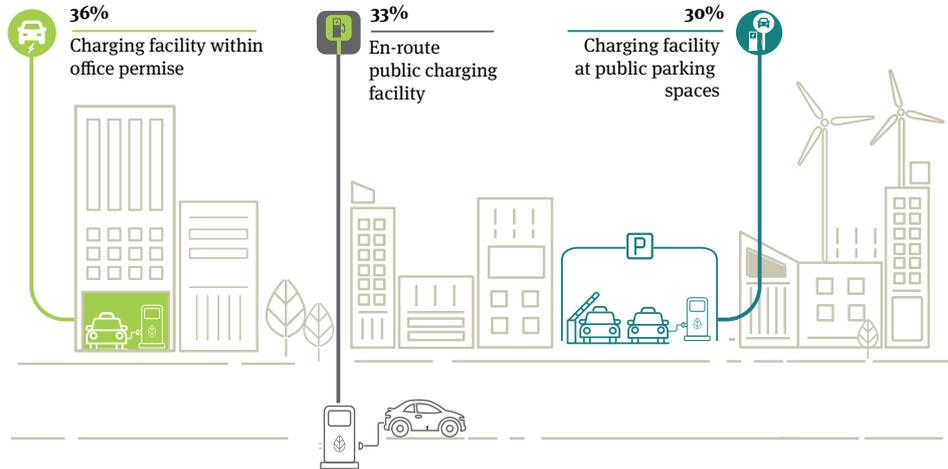
Unlike on-demand cab fleet, staff transport fleet does not show a strong preference for a particular charging facility. There is a slightly higher preference for charging at the office premises over the other two options. In the absence of hands-on experience of logistics fleet operators in using e-4Ws, through internal deliberation, a prediction of the segment's preferences is arrived at. The study finds that captive charging at logistics hubs is the overwhelming preference. The levels of preference for charging at en-route public charging stations and public parking lots are almost at par.

It is interesting to draw a contrast between charging service providers' thinking and the preference of fleet operators. It is found that the charging

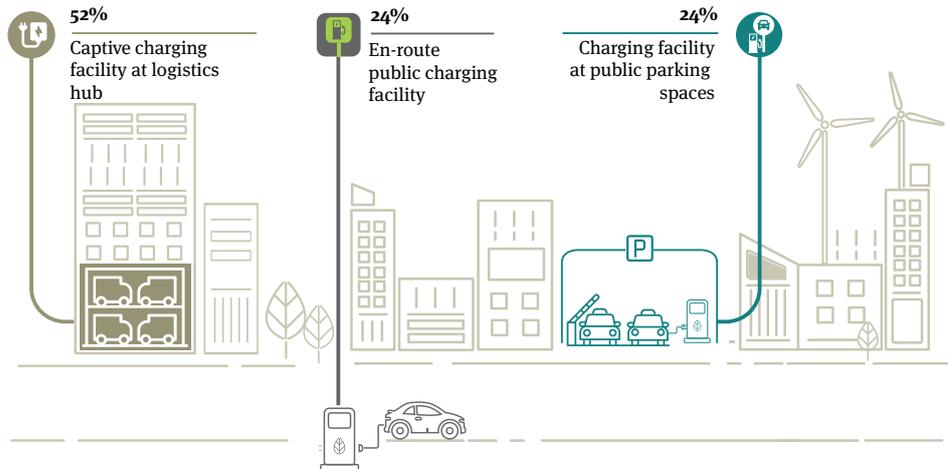
ON-DEMAND CAB FLEET



STAFF TRANSPORT FLEET

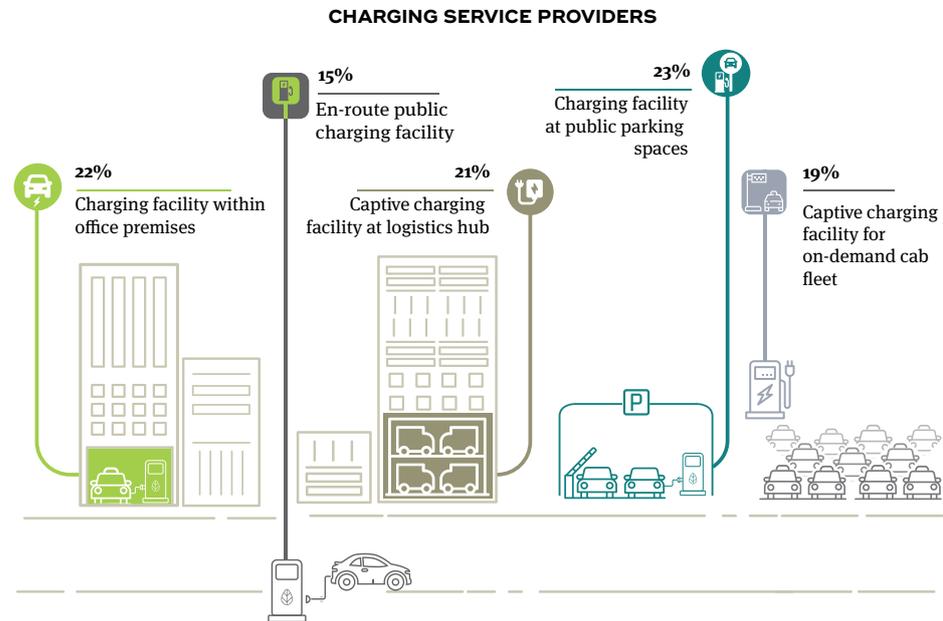


LOGISTICS FLEET



ES 3: CHARGING FACILITY PREFERENCES OF FLEET OPERATORS IN DIFFERENT SEGMENTS

service providers express almost the same level of preference for establishing charging stations at public parking spaces, within office premises, and at logistics hubs (Figure ES 4). **Setting up en-route public charging facilities is found to be the least preferable option, which could be attributed to the difficulty in finding space, along with the high expected cost of land rental in a city.**



ES 4: CHARGING FACILITY PREFERENCES OF CHARGING SERVICE PROVIDERS



THE EFFECTIVENESS AND ECONOMIC VIABILITY OF RUNNING A CHARGING FACILITY DEPEND ON ITS UTILISATION, WHICH, IN TURN, IS CONTINGENT ON THE SELECTION OF A GOOD LOCATION FOR THE CHARGING FACILITY.

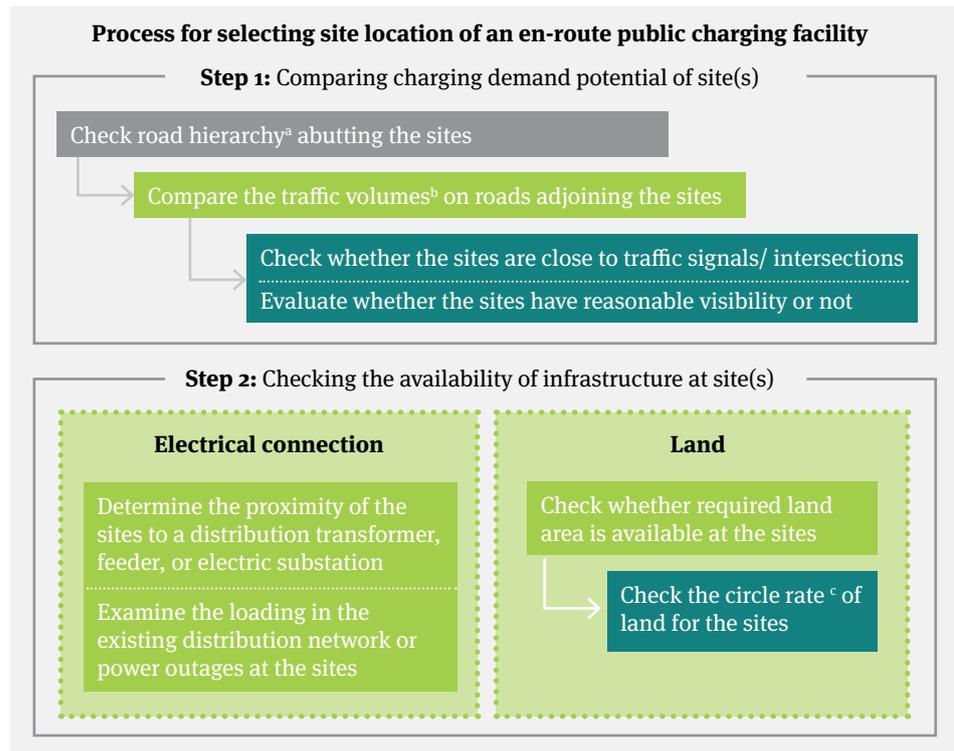
Site selection approach for public charging facilities

The effectiveness and economic viability of running a charging facility depend on its utilisation, which, in turn, is contingent on the selection of a good location for the charging facility. The study proposes a stepwise approach to locating the aforementioned charging facilities based on the following factors.

- **Charging demand potential:** The charging demand potential of prospective locations is evaluated in the first step as it is vital to understand whether the location have the potential to attract vehicular traffic and, thereby, charging demand.
- **Infrastructure availability:** The locations shortlisted on the ground of charging demand potential should be assessed in the next step based on the availability of requisite supporting land and electrical infrastructure.

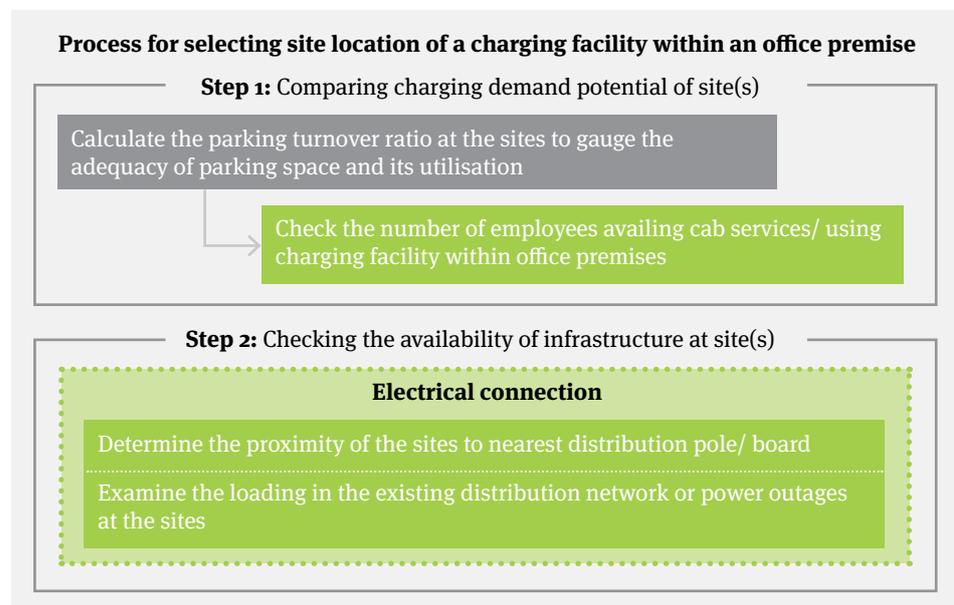
To compare charging demand potentials of prospective locations, certain sequential steps are proposed which depend on type of public charging facility.

Figures ES 5, ES 6, ES 7 and ES 8 illustrate the suggested approaches for different types of charging facilities.

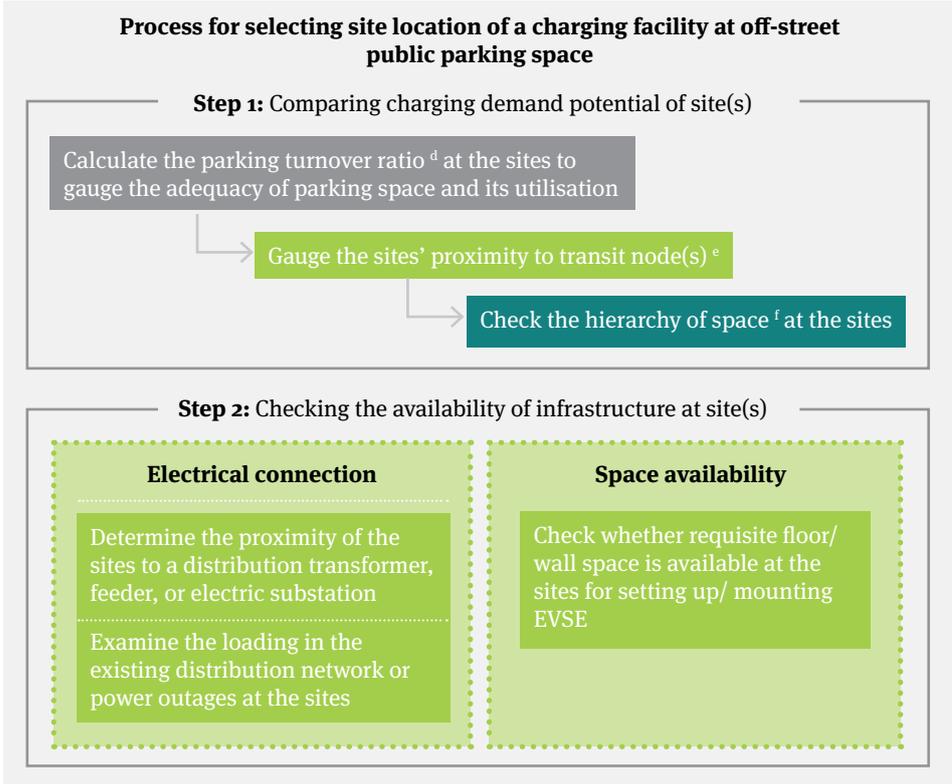


ES 5: SITE SELECTION APPROACH FOR EN-ROUTE CHARGING FACILITY

- a Road hierarchy, as set by the Indian Road Congress for all urban roads, determines the purpose, capacity, and functions of different types of roads in a city/ town's road network. Different types of roads include arterial roads, sub-arterial roads, local roads, etc. and could impact the charging demand.
- b The volume of traffic on a particular road could impact the charging demand and, thereby, the usage of a charging facility.
- c Land's circle rate is a proxy indicator for its market price.

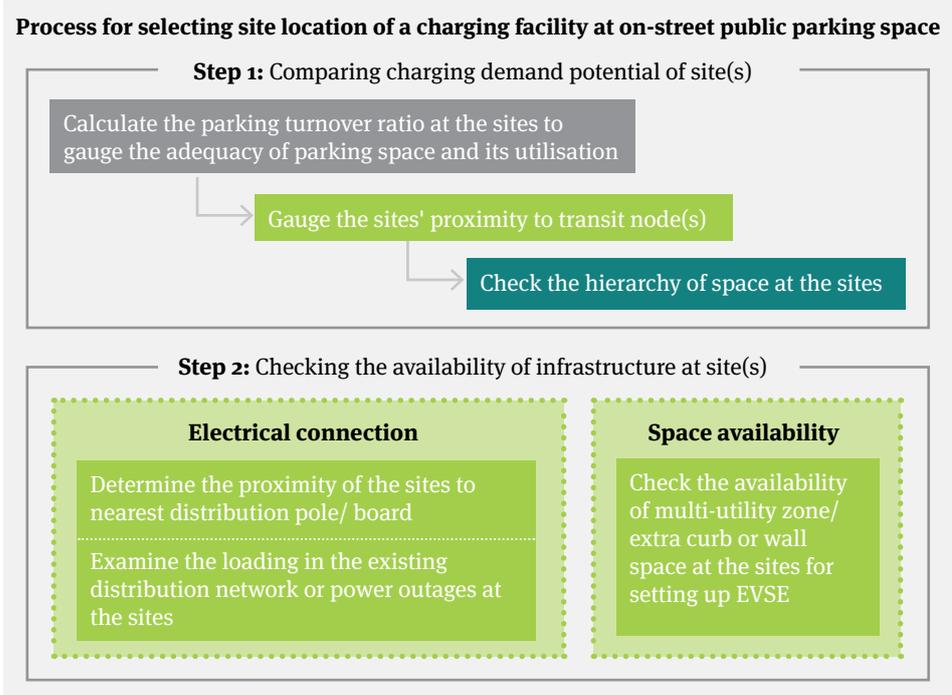


ES 6: SITE SELECTION APPROACH FOR CHARGING FACILITY WITHIN OFFICE PREMISES



ES 7: SITE SELECTION APPROACH FOR CHARGING FACILITY AT OFF-STREET PUBLIC PARKING SPACE

- d Parking turnover ratio is the ratio of parking demand to the total available parking bays in a parking space. It is used to evaluate the degree of usage of a parking space, which may vary based on the activity (retail/ office space, transport hub, etc.) it supports.
- e Transit nodes are the locations in the transport network of a city where one mode of transport meets another, such as railway stations, where rail-based transport meets road-based transport, or metro stations, where rail-based transport meets the road-based and walking-based transport. These nodes generally attract large volumes of traffic.
- f A hierarchy of all spaces where people congregate is given in the URDPFI guidelines. The higher the ranking of a space in that hierarchy, the higher the volume of citizens and traffic it attracts. For example, it would be more lucrative to invest in a large-scale charging facility in the central business district of an urban centre than in a convenience shopping centre that houses a milk booth, stationery shop, and grocery shop, because there is higher guaranteed usage of parking space in the former location.



ES 8: SITE SELECTION APPROACH FOR CHARGING FACILITY AT ON-STREET PUBLIC PARKING SPACE

Charging technologies for electric four-wheelers

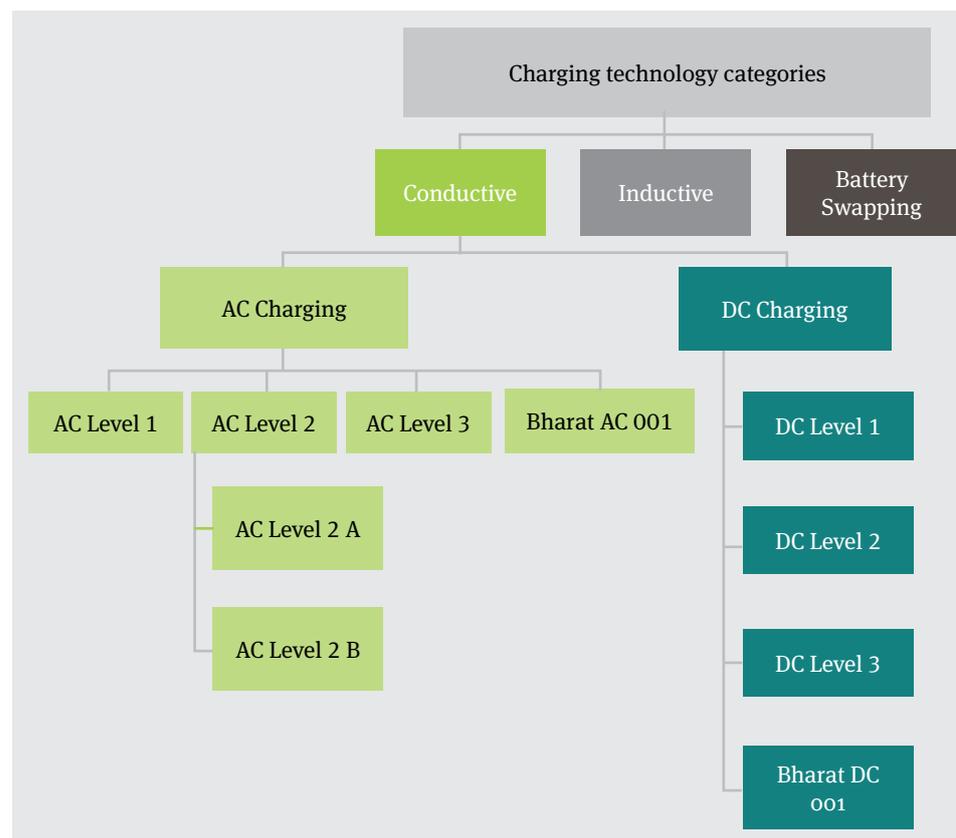
Understanding “where to charge” is not enough to ensure successful establishment of EV charging infrastructure; knowledge on “how to charge” i.e. charging technology, is equally important. Charging technologies currently deployed around the world vary in terms of functional attributes and applications. The absence of global standards for these technologies makes it challenging to categorise them. Nevertheless, to objectively assess these different technologies, a classification framework for charging technologies is required. The proposed framework, shown in Figure ES 9, also takes into account the standard practices followed in India’s distribution network¹. Moreover, it is important to study the charging technologies in the context of the existing e-4W models. The Indian EV market is characterised by two groups of e-4W models based on the battery voltage:

- Low Voltage (LV) e-4Ws: These cars have a battery voltage of **up to** 120V.
- High Voltage (HV) e-4Ws: These cars have a battery voltage **above** 120V.

Not all chargers would be suitable for both LV and HV e-4Ws.



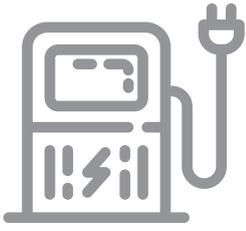
UNDERSTANDING “WHERE TO CHARGE” IS NOT ENOUGH TO ENSURE SUCCESSFUL ESTABLISHMENT OF EV CHARGING INFRASTRUCTURE; KNOWLEDGE ON “HOW TO CHARGE” I.E. CHARGING TECHNOLOGY, IS EQUALLY IMPORTANT



ES 9: E-4W CHARGING TECHNOLOGY CATEGORIES

An e-4W can be charged using conductive AC charging technology, provided the vehicle has an on-board charger. AC charging can be categorised into three levels: Level 1, Level 2, and Level 3, considering the common service voltages available worldwide. AC Level 1 charging category is not relevant in India, as the applicable service voltage level is not available.

¹ Standard voltages of 230V for single-phase circuits and 415/11000/33000V for three-phase circuits.



BHARAT AC 001 IS A SPECIAL TYPE OF AC LEVEL 2 CHARGER WITH A 10-KW THREE-PHASE INPUT AND THREE SINGLE-PHASE OUTPUT FOR CHARGING THREE EVS AT A TIME.

AC Level 2 (AC-II) charging entails single-phase charging performed at 230V outlets and is divided into two sub-classes based on charging power – AC-II (A) and AC-II (B). The former is simple plug and play charging using an on-board EV charger and a single-phase three-pin plug. It is suitable for LV e-4Ws which have on-board chargers rated at lower power levels, typically between 1 kW and 3 kW.

AC-II (B) charging is possible with car models that have on-board chargers rated at higher power levels, which a domestic socket² cannot provide. Hence, this charging method entails the use of dedicated wall-mounted charging points. Bharat AC 001 is a special type of AC Level 2 charger with a 10-kW three-phase input and three single-phase output for charging three EVs at a time.

AC Level 3 (AC-III)³ is only possible when the vehicle has a three-phase AC charger. In the Indian context, vehicles only have single-phase chargers, and the highest observed charging capacity is 7.4 kW. In contrast, in the European market, there are cars with three-phase 22 kW on-board chargers.

DC plug-in charging entails charging via a plug-in connection. DC plug-in chargers can be further classified into multiple levels based on power output. Level 1 (DC-I) and Level 2 (DC-II) DC chargers are generally used for charging e-4Ws. DC Level 3 (DC-III) chargers of 175 kW are new in the market, but not suitable for existing EV models in India. Bharat DC 001 is a special category of EVSEs specifically designed at an output voltage level suitable for charging the existing LV e-4W models⁴ in India.

Battery swapping and inductive charging are not the ideal solutions for charging current e-4W models. The requirement for significant EV modification and high installation and operational costs are two major barriers to their implementation.

The shortlisted charging technologies for LV and HV e-4Ws are presented in Table ES 10.

ES 10: CHARGING TECHNOLOGIES APPLICABLE TO LV AND HV E-4WS

| Charging technology | Applicability to LV and HV e-4Ws | |
|---------------------|----------------------------------|-------------|
| | High Voltage | Low Voltage |
| AC-II (A) | Yes | Yes |
| Bharat AC 001 | Yes | Yes |
| AC-II (B) | Yes | No |
| Bharat DC 001 | No | Yes |
| DC-I | Yes | No |
| DC-II | Yes | No |

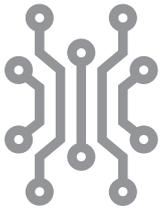
² Domestic 3-pin sockets are 6/16A in India, much less than the maximum output current of 32A in AC-II charging.

³ This type of charging is often called Type 2 AC charging, based on the connector developed in the European market for charging.

⁴ Typical battery voltages of e-4Ws are well above 150 V in established EV markets.

Selection of “best-fit” charging technologies

The multiplicity of technologies available in the market, with each technology having its own set of pros and cons, makes it hard to select the “best-fit” charging technology. The effectiveness and feasibility of deployment and use of a charging technology depend on a range of factors, both technical and economic. The technology should satisfy the criteria for charging the vehicle (e.g. charging time, grid infrastructure needed, proximity to grid, etc.), and its implementation should be cost-effective. Selection of a suitable charging technology may involve trade-offs.



THE MULTIPLICITY OF TECHNOLOGIES AVAILABLE IN THE MARKET, WITH EACH TECHNOLOGY HAVING ITS OWN SET OF PROS AND CONS, MAKES IT HARD TO SELECT THE “BEST-FIT” CHARGING TECHNOLOGY.

Recognising the possible complexity in pinpointing the best-fit technology for e-4W charging, a methodology based on a composite Multi-Criteria Decision Matrix (MCDM) is proposed for each type of public charging facility. An MCDM consists of a set of techno-economic parameters, each assigned a weight based on the assessed degree of importance. The charging technologies are evaluated separately in the context of the three types of public charging facilities. Also, separate MCDMs are constructed for LV and HV e-4W models, due to the fact that these categories of e-4Ws can only be charged using certain types of technologies. Table ES 11 presents the list of best-fit charging technologies identified by the MCDMs for LV and HV e-4Ws.

ES 11: BEST-FIT TECHNOLOGIES FOR E-4W CHARGING AT DIFFERENT TYPES OF CHARGING FACILITIES⁵

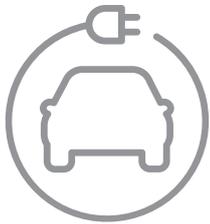
| Charging facility type | Best-fit charging technologies | |
|--|--------------------------------|--------------|
| | Low Voltage | High Voltage |
| En-route public charging facility | Bharat DC 001 | DC-II |
| Charging facility at public parking space ⁵ | AC-II (A) | AC-II (B) |
| Charging facility within office premises | AC-II (A) | AC-II (B) |

MCDM results may vary based on the characteristics of a specific location. For certain locations, additional costs (such as the cost for cabling) and more time (e.g. to get permission for road-cutting) may be required to get the necessary electricity connection.

One should consider MCDM results with some level of caution. The global and Indian EV markets are both still at a nascent stage, and the technical design of EVs and chargers is continuously being updated, which may impact the technical and economic viability of the concerned charging technologies in the coming months. Therefore, one has to remember that the parameters considered in the MCDMs and the results reflect the current context and may change in the future as the EV market evolves.

⁵ In the case of best-fit charging technology selection for charging facilities at public parking spaces, there is no need for developing separate MCDMs for off-street and on-street parking, as there is no difference in the parameters considered for selection in these two categories.

Stakeholder collaboration in charging infrastructure deployment



THE GLOBAL AND INDIAN EV MARKETS ARE BOTH STILL AT A NASCENT STAGE, AND THE TECHNICAL DESIGN OF EVS AND CHARGERS IS CONTINUOUSLY BEING UPDATED, WHICH MAY IMPACT THE TECHNICAL AND ECONOMIC VIABILITY OF THE CONCERNED CHARGING TECHNOLOGIES IN THE COMING MONTHS.

The availability of charging infrastructure is an important requirement for e-4W adoption in India. Although there are guidelines for setting up public charging stations and also, financial schemes to support the implementation, deployment of charging infrastructure which can address EV users' range anxiety is yet to see much traction. There are dependencies on various stakeholders to realise on-ground implementation.

The primary requirement for establishing an EV charging facility is the land for EV parking during charging. The challenge with the land is two-fold: its availability and cost. In Tier-I and Tier-II Indian cities, availability of space at the desired locations could be the biggest hurdle to implementation. This lack of availability results in high land rental costs, which, in turn, directly drives up the charging service cost and negatively affects the charging businesses' viability. Urban Local Bodies (ULBs), the custodians of public land in cities, can potentially play a critical role in supporting the interested charging service providers in getting the necessary space. Not only do ULBs have land they can lease, but they also manage parking lots across cities, where space can be earmarked for EV charging bays. The charging service provider and ULB may enter into a lease agreement based on a revenue sharing model.

In the implementation of a charging facility, the vital role of the power distribution utility cannot be over emphasised. From providing a timely electricity connection for the required sanctioned demand, to supplying uninterrupted electricity, to metering and billing and, gradually, implementing Vehicle-Grid Integration, the power distribution utility's part is very crucial.

The State Nodal Agency (SNA), responsible for selecting an Implementation Agency to set up, operate, and maintain public charging facilities in the state, is also an important stakeholder. SNA could potentially play the important role of go-between among different stakeholders - engaging the concerned players and ensuring effective coordination, especially in order to address implementation hurdles. Apart from facilitating charging facility deployment, SNA has the mandate to limit the fees charged by a charging service provider at a public charging facility⁶. There are other activities that also involve the SNA, such as accessing charging station data, disbursing subsidies to charging service providers, etc. A summary of the key stakeholders' possible roles is presented in Figure ES 12.

⁶ This is applicable in the case where the public charging facility has been set up with government incentives.



ES 12: MAPPING OF POSSIBLE KEY STAKEHOLDER ROLES IN FACILITATING CHARGING INFRASTRUCTURE ROLL-OUT IN AN INDIAN CITY

The bottom line is that understanding a charging service provider's requirements and realising the coordination and/ or collaboration between the public agencies and the interested investor in order to satisfy these requirements are vital to quickly achieving large-scale roll out of public EV charging infrastructure.

