Location Planning for

Public Electric Vehicle Fleet Charging Stations

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Center for Study of Science, Technology and Policy

October 21

Designed and edited by CSTEP

Disclaimer

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(The author list provided assumes no particular order as every individual contributed to the successful execution of the project.)

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Executive Summary

Electric mobility has gained momentum worldwide as a sustainable choice in reducing greenhouse gas emissions and improving air quality. However, the adoption rate of electric vehicles (EVs) is low because of driving range anxiety, high upfront costs, and the lack of public charging infrastructure. A robust public charging infrastructure can reduce range anxiety and increase the EV adoption rate. Our study focuses on identifying locations for public charging stations to service intermediate public transport (IPT) and develop a scalable and replicable framework to identify such charging locations in the future based on available data. The focus is on IPT and public transport (PT) specifically, as the distance travelled by these segments per day is higher than the existing battery range.

Based on literature review and stakeholder consultations, we identified four key parameters that govern the charging station locations: demographics, land use and transport, vehicle specifications, and electric infrastructure. These parameters form the basis of the location assessment framework for public EV fleet charging stations. Bengaluru has been identified as the study area based on its EV initiatives such as electric bus trials, the introduction of electric rickshaws and electric cabs, and the formulation of the EV policy. The city also has public charging stations installed by BESCOM at various locations.

Analyses based on secondary data have shown that high-density peripheral areas and major junctions and corridors in Bengaluru have not been considered while planning the existing charging stations.

Based on parking space availability, major transit centres such as Shantinagar, Laggere, Banashankari, and Kengeri could be potential areas for setting up charging stations. In light of existing/proposed substations, public parking lots, and fuel pumps and by virtue of being high-density corridors, Bellandur, Devasandra, Thanisandra, Horamavu, HMT, and Peenya also have the potential for setting up charging stations in the future.

Further, the study estimates that by 2031, Bengaluru would be home to ~4 lakh autorickshaws, ~3 lakh cabs, and 1.3 lakh buses. Based on this estimate, the study has developed three EV penetration scenarios: business as usual (2%), pragmatic scenario (revised policy target: 30%), and best-case scenario (actual policy target: 100%). In the pragmatic scenario, ~9,00,000 MWh of energy would be required to charge EVs in the IPT and PT segments, and carbon dioxide (CO_2) emissions would reduce by 1.1 kilotons. With 100% EV penetration, the energy demand would rise to ~30,00,000 MWh and CO_2 emission would reduce by 4 kilotons annually.

Apart from location identification, the other challenges in setting up public charging stations are unidentified business models, availability of affordable real estate, and low utilisation rate. Based on stakeholder consultations and analysis, it could be estimated that identifying proper locations and targeting existing public parking lots could reduce the upfront cost and increase the utilisation of public charging stations.

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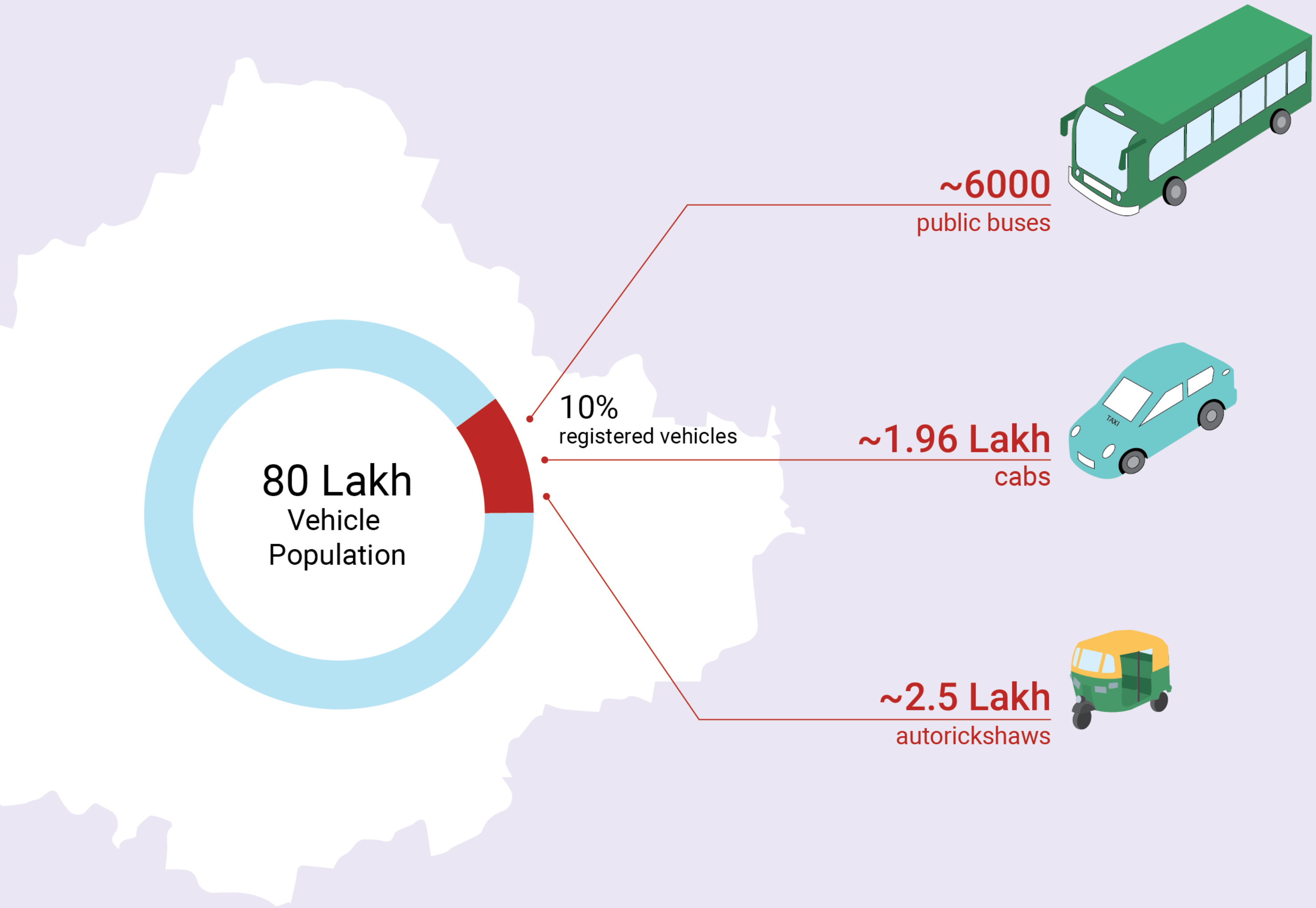
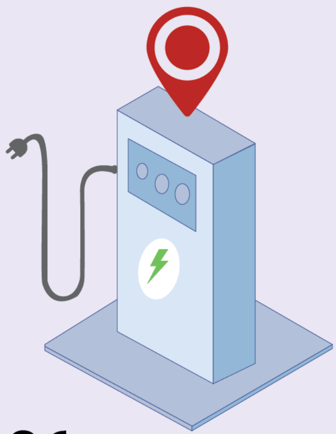
Abbreviations

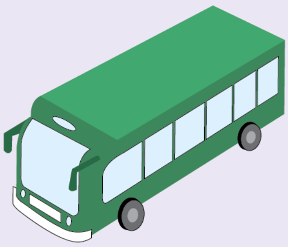
BESCOM	Bengaluru Electricity Supply Company
BBMP	Bruhat Bengaluru Mahanagara Palike
BDA	Bangalore Development Authority
BMTC	Bengaluru Metropolitan Transport Corporation
CAGR	Compound annual growth rate
CBD	Central business district
CEA	Central Electricity Authority
CS	Charging station
EVs	Electric vehicles
GIS	Geographic information system
GoI	Government of India
GoK	Government of Karnataka
GWh	Gigawatt-hour
ICE	Internal combustion engine
IPT	Intermediate public transport
KT	Kilo tonnes
KWh	Kilowatt-hour
MoP	Ministry of Power
O-D	Origin-destination
PCS	Public charging stations
PT	Public transport
TTMC	Traffic Transit Management Centre





136 charging stations
installed at **70** locations in
Bengaluru in 2020

Plans to introduce



90
electric buses

~10,000
electric
rickshaws

1. Introduction

India is gearing up for a transition to electric mobility to reduce transport-related energy consumption and emissions. The main challenges in adopting electric vehicles (EVs) are high upfront costs and the range anxiety arising from a lack of public charging infrastructure. Even though EV penetration is minimal at the moment in India, it is projected to increase in the long run because of spiralling fuel costs, low maintenance, and the energy efficiency of EVs.

In 2018, the Government of India (GoI) issued guidelines and standards (Ministry of Power, 2019) to install public EV charging infrastructure based on the requirements of various vehicle segments. The guidelines suggest at least one charging station in a 3 x 3 km grid and one fast-charging station every 25 km on both sides of highways or roads in urban areas. For long-distance travel and heavy-duty vehicles such as trucks and buses, at least one fast-charging station every 100 km on each side of the highway has been mandated.

To support this initiative, the Ministry of Power (MoP) has permitted individuals and private entities to set up public charging infrastructure without license, provided they fulfil the technical and performance standard laid down by the MoP and the Central Electricity Authority (CEA; Ministry of Power, 2018). Such public charging stations could be installed in residences, malls, office complexes, restaurants, hotels, and so forth. They could charge vehicles of residents, owners, employees, and visitors on the premises. Currently, many private players are constructing public charging stations and developing mobile applications to help consumers track and locate the nearest charging station, its availability, and its pricing.

Other developments include the 2020 notification from the Ministry of Road Transport and Highways (MoRTH), permitting the sale of EVs without batteries to reduce the upfront cost of EVs compared to conventional vehicles. With this, battery swapping is expected to get a push, thereby reducing charging time and range anxiety. Cities should, therefore, prioritise the creation of a well-planned public charging infrastructure to boost EV acceptance in India.

Good EV charging infrastructure is the key to fleet electrification and sustainable transport. This study focuses on developing a framework for identifying potential locations, considering the demand for public EV fleet charging infrastructure in Bengaluru. The factors considered include demographic (e.g., high population areas), land-use (e.g., residential or commercial), and transport (e.g., travel pattern and high-density corridors) aspects.

Electrification in the passenger fleet segment in Bengaluru has already gained momentum with the Bengaluru Metropolitan Transport Corporation (BMTC) going the electric way. BMTC conducted electric bus trial runs in October 2020, and these trials would continue with different manufacturers for a thorough assessment. BMTC has also got sanction from the Department of Heavy Industries (n.d.) to deploy 300 electric buses in the city. The transition to electric in other fleet segments (cabs, minibuses, and private buses) will also impact the environment positively if it is streamlined. For fleet charging, the fleet characteristics (operational kilometres, operational hours, halt time, off-peak hours, etc.) need to be considered to estimate demand.

1.1. Status of EVs and Charging Infrastructure in Bengaluru

Bengaluru has a vehicle population of about 80 lakh, but transport vehicles (taxies, trucks, light goods vehicles, buses, and three-wheelers) make up only 10% of the total registered vehicles. These include ~2.5 lakh autorickshaws, ~1.96 lakh cabs (Transport Department, Karnataka, 2020), and ~6,000 public city buses (BMTC, 2020, p. 22).

The number of vehicles in Bengaluru grew at a compound annual growth rate (CAGR) of 10% from 2014–15 to 2018–19. Though the share of EVs is just 1%–2% at present, there is great potential for expanding the EV penetration, given the initiatives and trials.

According to Phase II of the Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles in India (FAME) Scheme, 2,636 EV charging stations were sanctioned (Ministry of Heavy Industries & Public Enterprises, 2020) in 62 cities spread across various states. BESCOM installed 136 charging stations at 70 locations in Bengaluru in 2020. These chargers are located in different government premises such as the BESCOM office, BMTC buildings, Traffic Transit Management Centre (TTMC) buildings, and Bengaluru Development Authority (BDA) complexes in different parts of the city—Ambedkar Veedhi, Indiranagar, Old Airport Road, BTM Layout, Mysore Road, RR Nagar, Banaswadi, Kathriguppe, Peenya, and Yelahanka. They offer tariff rates as per the Karnataka EV policy 2017 (Commerce and Industries Department, GoK, 2017).

On the e-mobility promotion front, Bengaluru has carried out multiple electric bus trial runs. The BMTC recently issued a work order to NTPC Vidyut Vyapar Nigam Ltd and JBM Auto to run 90 electric buses on select routes (Menezes, 2021). Also, there are plans to introduce ~10,000 electric rickshaws in Bengaluru.

Considering the number of vehicles, the number of trips, average trip lengths, and emission factors, transport vehicles—buses, cabs, and autorickshaws—contribute substantially to carbon dioxide (CO_2) emissions. Though the actual number of fleet vehicles in the city seems to be marginal compared to the total vehicle population, their fuel consumption and emissions are high given the kilometres per day travelled. The four-wheeler segment including cars and cabs contributes to approximately 60% of the passenger transport emissions based on fuel efficiency and average daily run. The deployment of charging infrastructure across the city may boost EV acceptance, thus reducing air pollution and emissions from the transport sector in the city.

1.2. Objectives

- Develop a scalable and replicable framework to determine appropriate locations for public EV charging stations for fleet vehicles
- Estimate demand for public EV charging infrastructure location-wise for fleet vehicles

- Estimate the location-wise energy requirement for fleet charging and the emission-reduction potential
- Identify the challenges in installing public charging infrastructure in Indian cities

1.3. Study Area

The study area for this project was restricted to the Bruhat Bengaluru Mahanagara Palike (BBMP) boundary (Figure 1). Key ward-wise parameters such as population, land-use, and travel patterns were considered while analysing the study area.

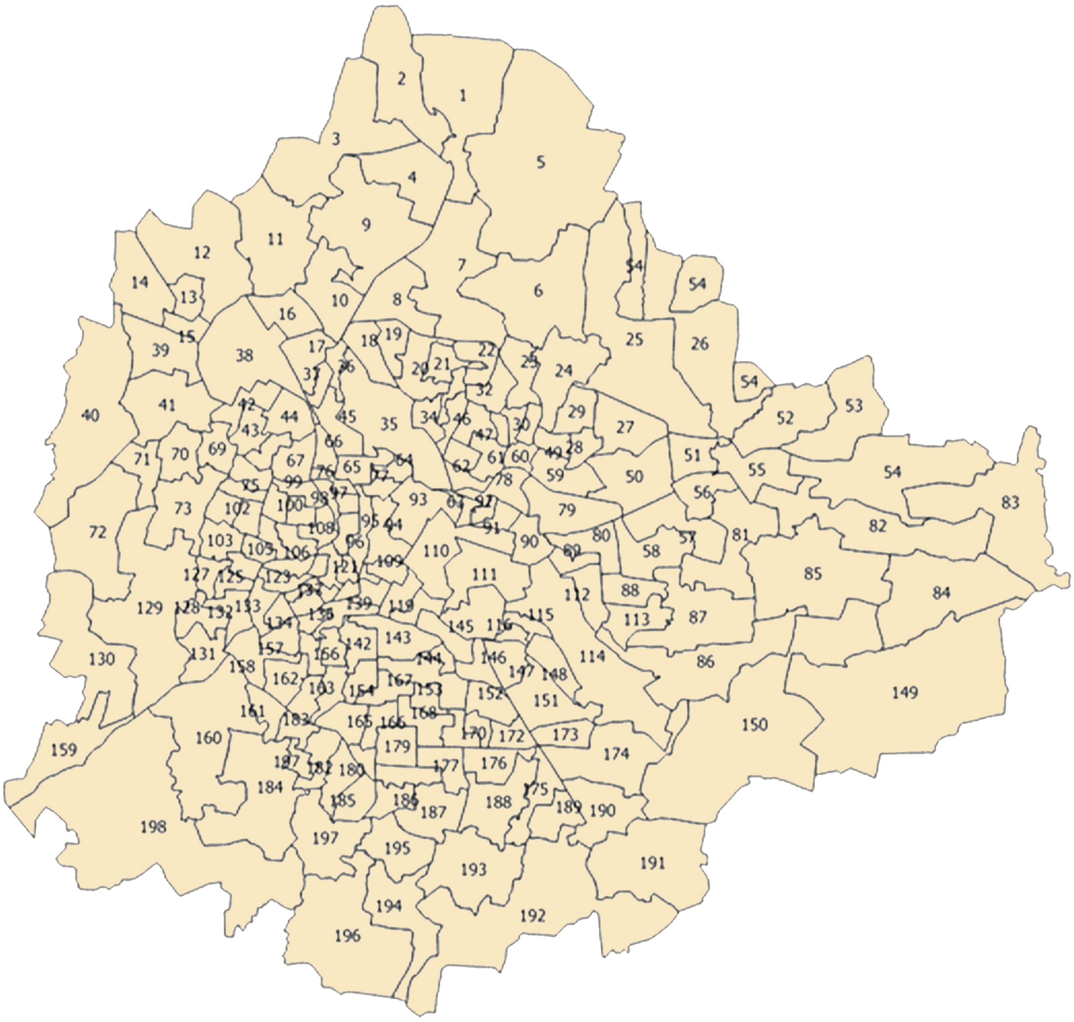


Figure 1: BBMP area map with wards

2. Literature Review

Several studies have been conducted worldwide to determine suitable locations for EV public charging stations. The studies use different approaches suited to the region, considering data availability. The most predominantly used approaches are the flow-based approach, the point-based approach, and the polygon-based approach (Csiszár et al., 2019). The key parameters considered for analysis in the studies include traffic data such as traffic volume, energy consumption, travel patterns, vehicle characteristics, population, parking locations, location-specific cost, land-use data, and the type of charger. A brief overview of the studies is given below.

A decision-support system was proposed for finding ideal locations for installing charging stations to meet the electric taxi vehicle demand in Vienna, Austria (Asamer et al., 2016). Demand was estimated based on the taxi operational data (trip origin and destination zones).

A land-use approach based on weighted multi-criteria was developed to identify potential charging locations in Budapest, Hungary (Csiszár et al., 2019). This study assumed a certain number of charging stations to be deployed and worked out the distribution pattern. A two-scale (macro and micro) charging station locating method to support short trips by EVs was considered. The study did not aim to determine exact locations and identifies potential zones, leaving the responsibility of identifying the exact locations to local authorities.

Key findings from a Natural Resource Defence Council report on charging locations in India indicate that park and ride facilities close to major activity centres and high-density areas are feasible for public charging station locations. In addition, approaches for location planning of charging infrastructure include the local knowledge and stakeholder approach, the modelling approach, and the hybrid approach (Jaiswal, 2020). The advantages and disadvantages of these approaches are discussed, and a suitable approach based on the size of the study area is recommended.

- In the local knowledge and stakeholder approach, high public acceptance, ease of implementation, use of local knowledge, and lesser data requirement are a few advantages. However, this approach is not robust and is not suitable for huge urban areas.
- The modelling approach is technically sound, less time-consuming, cost-effective, and suitable for any type and size of the area but will require comprehensive data sets, which might not always be available or might be difficult to collect or generate.

- The hybrid approach, as the name suggests, is a mix of both. This approach uses modelling wherever possible or required according to data availability and allows the use of local and stakeholder knowledge wherever modelling is not possible. It saves time by partial modelling use and has backing from local authorities and the public because of local knowledge and stakeholder consultations. This approach is not economical for small areas and is good to serve medium and large areas.

A review of the global literature available on EVs and charging stations revealed a few important stylised facts that govern the need for charging infrastructure (Funke et al., 2019). In most countries, the availability of charging infrastructure had a positive impact on EV adoption. Factors governing the availability of public charging stations were market EV share, per capita EV ratio, vehicle to refuelling station ratio, and charging locations to gasoline station ratio.

Home charging was sufficient during the early diffusion stages of EVs, and slow public charging stations as a substitute to home charging did not significantly impact EV adoption. Based on literature review, data requirement, and data available, a methodology and analysis framework was developed for this study. The framework considers land use, city development proposals, demographic trends, travel characteristics, and space availability (parking lots) to identify potential locations for setting up public charging stations. This study also estimates the energy requirement and local CO_2 reduction potential under different scenarios of EV penetration.

3. Assessment Framework

The assessment framework has four dimensions (Figure 2). The first dimension is the focus area, concentrating on demographics (population density) and socio-economic characteristics. The second dimension is data related to land use, traffic, and transport (origin-destination [O-D], traffic volume, parking locations, etc.). The third dimension is EV characteristics such as battery range, charger type, charging time, and policy targets specific to each vehicle category. The fourth dimension is the electric grid infrastructure, which is key for decision-making related to potential charging stations. This dimension focuses on current policy measures encouraging grid infrastructure to adopt EVs and considers the existing and planned electric grid infrastructure such as transformers and substations. For the study area, a methodology was developed for carrying out the location planning for public EV fleet charging stations based on this assessment framework.

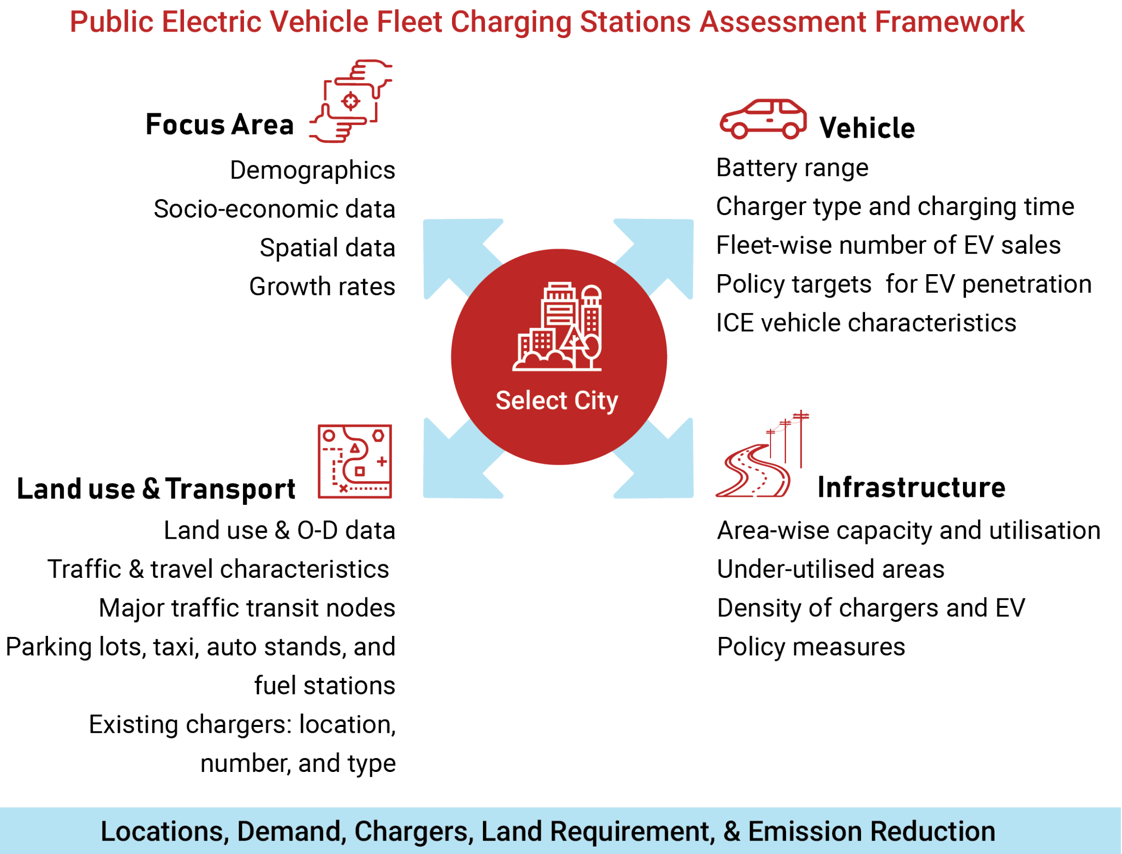


Figure 2: Framework for location planning analysis of public charging stations


1
Literature Review
2
Data Collection
3
Analysis
4
Results

4. Methodology

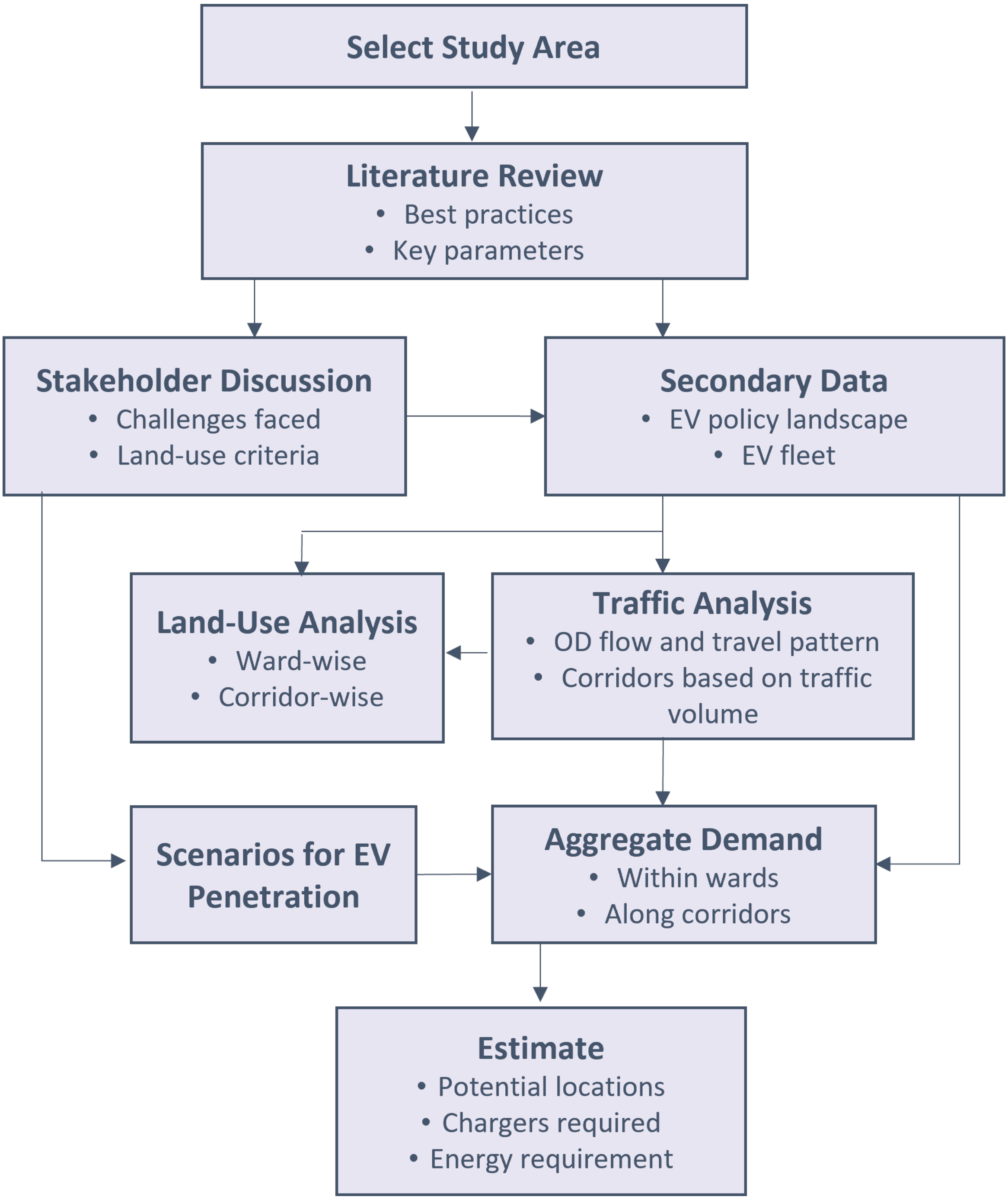


Figure 3: Methodology for location planning analysis of public charging stations

4.1. Selection of the Study Area

The study area for this project was selected based on EV preparedness and actions. Bengaluru has a state EV policy. The city has conducted a trial run for electric buses in 2020 and plans to mobilise an electric bus fleet soon. BESCOM has opened public charging stations at various locations in the city, and there are also many other private-owned public charging stations. The city also has a few e-cab services, such as Lithium and SainikPod. There are 14,579 (Philip, 2021) EVs registered in Bengaluru. Though this is a small number compared to the total number of vehicles in Bengaluru, incentives such as subsidies and tax benefits and action plans such as technical support for EV adoption are likely to give a boost for increased adoption.

4.2. Secondary Data Collection

As the time frame was restricted to three months, the study relied on secondary data for analysis. Authorised documents such as the Master Plan; Comprehensive Traffic and Transportation Plan; and Annual Report, Transport Department, Karnataka, were used for fetching the required data. Census data were used for growth rate and population projection. Stakeholder consultation was carried out to collect data on existing charging stations, receive inputs/feedback on the assessment framework, and understand their challenges.

Ward boundaries were considered for detailed location analysis. The analysis considered proposed land use and development, demographic characteristics, travel patterns, EV adoption trends and policy targets, and vehicle growth trends.

Demographic data from Census 2011, existing and proposed land-use data from the Revised Master Plan, 2031, transport and traffic data for IPT from various studies specific to Bengaluru, vehicle specifications based on the existing IPT EV models, and the existing and proposed substation data for grid infrastructure analysis from BESCOM data were considered for this analysis.

4.2.1. Demographic Analysis

Figures 4 and 5 show the ward-wise population of Bengaluru for the years 2021 and 2031. The peripheral areas have a high population compared to the Central Business District (CBD) and surrounding areas. Most of these high population wards do not have charging stations at present and, hence, could be identified as potential areas for setting up future charging infrastructure. These charging stations could include single point, multiple points, fast chargers, slow chargers, and public- and private-owned stations.

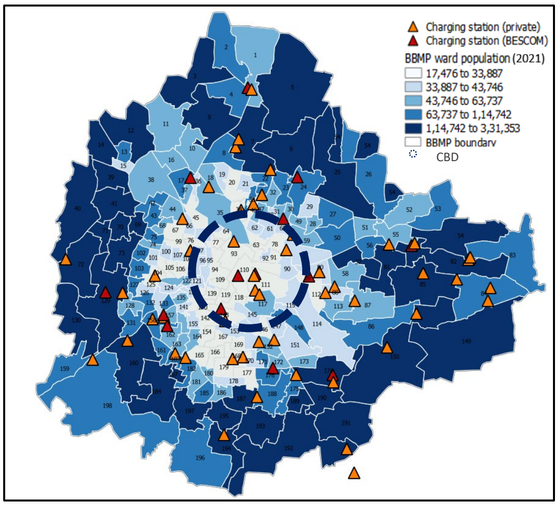


Figure 4: Ward-wise population of Bengaluru, 2021

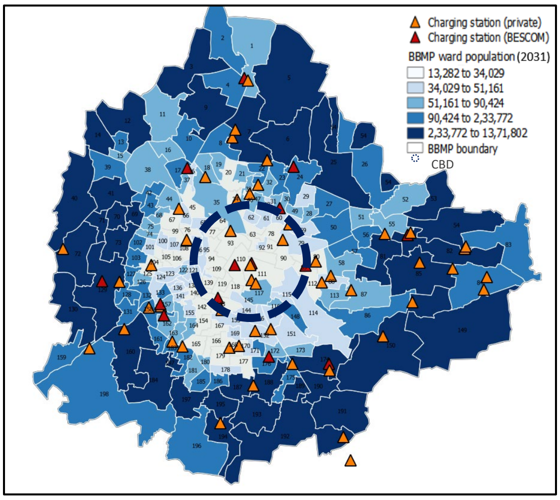


Figure 5: Projected ward-wise population of Bengaluru, 2031

4.2.2. Land-Use Analysis

A comparison of the current land use (Figure 6) and proposed land use (Figure 7) was carried out to identify areas proposed for future development (BDA, 2017). Figure 7 shows that significant residential development is proposed in the peripheral area and more commercial development is proposed in the CBD area. A map of existing charging stations was overlaid on the proposed land-use map. It was seen that the CBD area has a dense network of charging stations, whereas the peripheral residential areas do not have any charging stations yet.

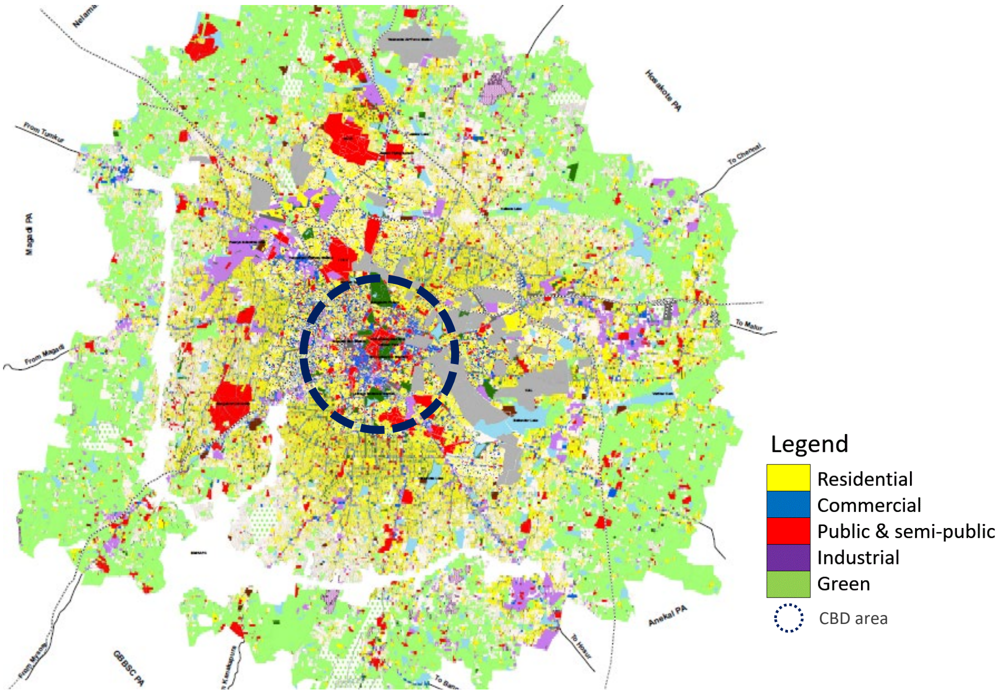


Figure 6: Existing land-use map, Bengaluru, 2015

4.2.3. Transportation Analysis

For transportation analysis, various factors such as existing high-density corridors, transit centres (metro stations, depots, TTMCs, etc.), public parking locations, public transport network, and travel pattern (trip generation and termination wards) were considered. Individual analyses were carried out to understand the potential areas for setting up charging infrastructure based on these parameters.

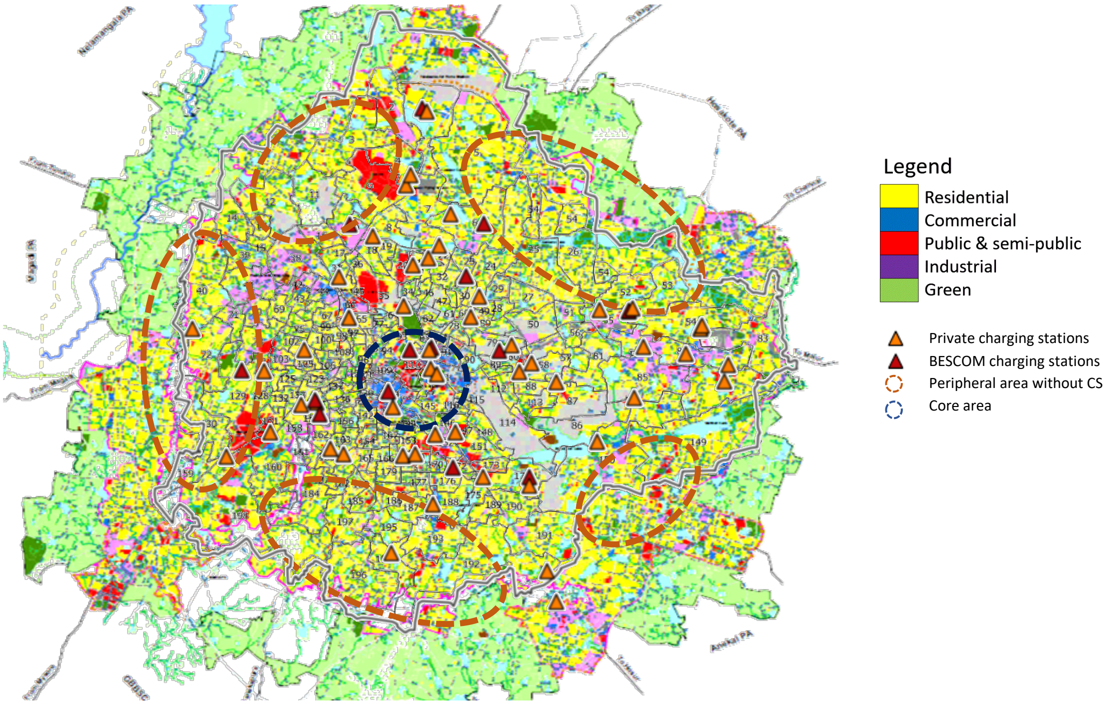


Figure 7: Proposed land-use plan, Bengaluru, 2031

4.2.3.1. Major Transit Centres and Corridors

Major transit centres such as metro stations, bus depots, and TTMC are potential locations for park and charge. Figure 8 shows the major transit centres in the study area and marks potential locations for charging stations. These locations are major metro stations or TTMCs where parking is available or areas where more than one transit centre exists in the vicinity.

Figure 9 shows high-density corridors in the study area. Major corridors help identify locations for fast-charging stations for opportunity charging and can facilitate long-distance travel. From the map (Figure 9), it can be seen that very rarely are charging stations located at major junctions or corridors. This could be one of the reasons for the low utilisation of public charging stations in Bengaluru. There are a few on Outer Ring Road and just one or two on Marathahalli Main Road, Magadi Road, and Bannerghatta Main Road. The other corridors could be potential locations for fast-charging or battery-swapping stations. For transit centres, potential locations could be identified for setting up charging stations based on the footfall and available parking space.

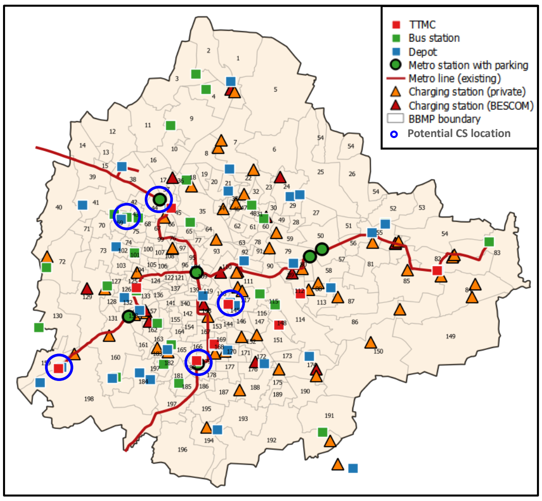


Figure 8: Map showing major existing transit centres in Bengaluru

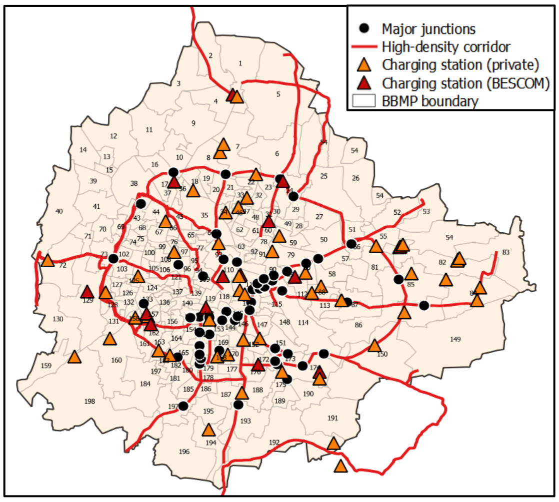


Figure 9: Map showing high-density corridors and major junctions in Bengaluru

4.2.3.2. Parking Locations

Figure 10 shows public parking locations in Bengaluru. The type of charger to be installed will be based on the activities in the surrounding areas and the time associated with those activities. Slow chargers that take 6–8 hours to charge could be provided for office parking, institutes, and so forth. Level 2 chargers that take 3–4 hours to charge could be provided at shopping or commercial areas, hospitals, and institutes.

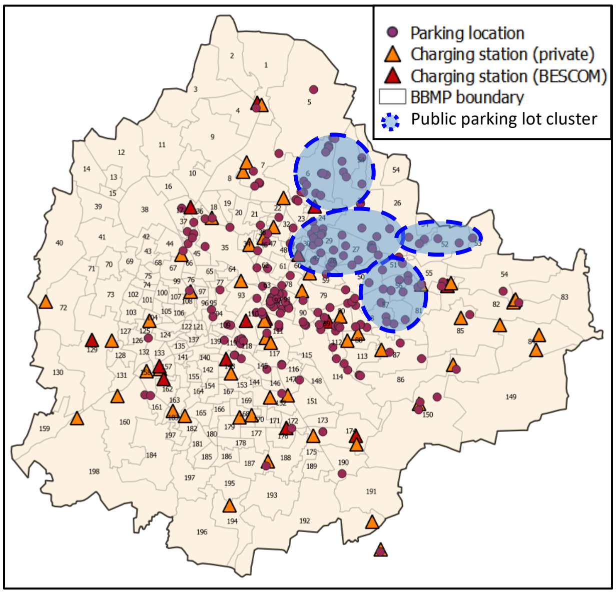


Figure 10: Existing public parking locations in Bengaluru

The map also shows a cluster of public parking spaces where existing public charging is not present. These spaces could be potential areas for future charging stations.

4.2.3.3. Data analysis

Based on the available secondary data, major trip-generating and trip-attracting wards were identified and travel characteristics of airport trips were analysed (Figure 11). The Kempegowda International Airport, Bengaluru, was considered a trip-generating point, or origin. The wards to which the trips were made became trip-attracting areas. Figure 11 shows major trip-generating or trip-attracting wards. Some of these wards do not have charging stations and could be potential wards for setting up new charging stations. Using the travel data from cab aggregators, a city-level analysis can be carried out to identify major trip-generating and trip-attracting wards for setting up public charging stations.

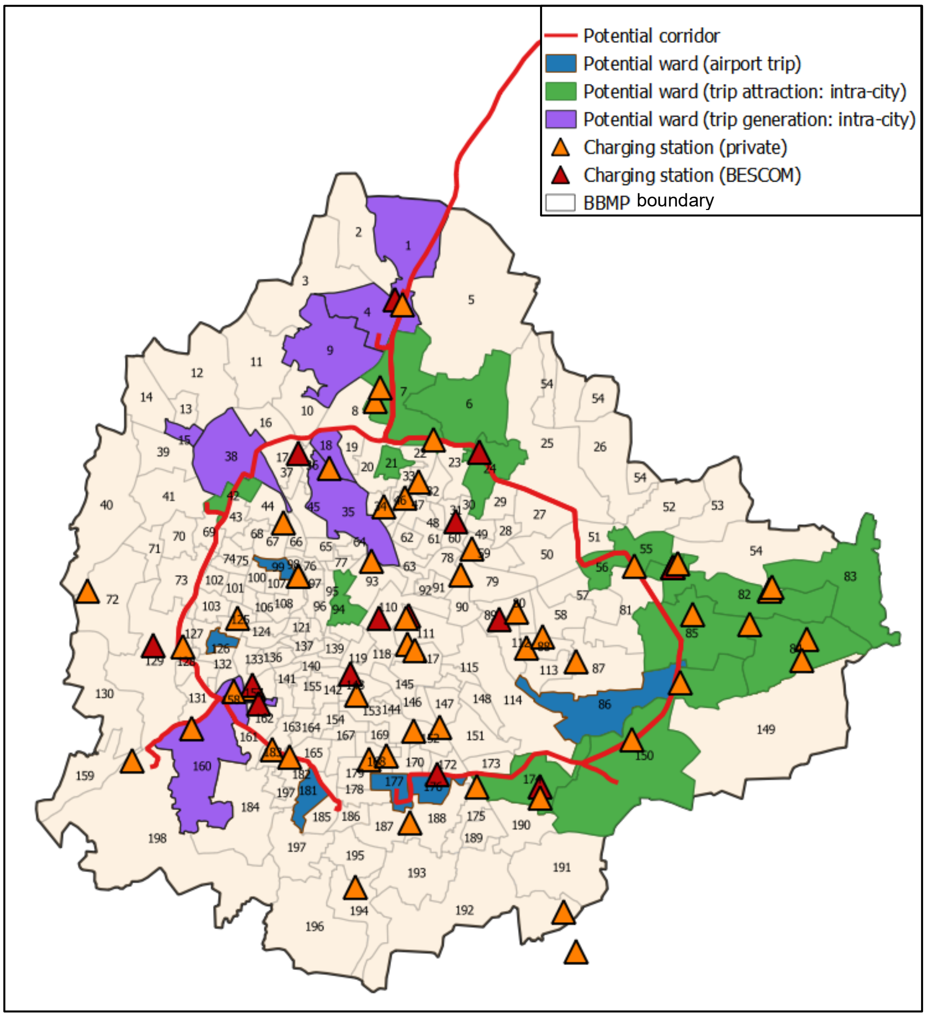


Figure 11: Map showing trip-generating and trip-attracting wards

4.3. Index Calculation

To aggregate all the parameters mentioned, an index value calculation method was used to identify potential locations. This calculation considered the existing infrastructure and facilities (such as parking and substations) to minimise cost and social impacts, and maximise resources utilisation (Lucas et al., 2018). Other studies consider weighted overlay analysis using the geographic information system (GIS) to identify suitable regions for charging infrastructure (Erbas et al., 2018; Shrestha, 2019). The weighted overlay analysis is required to build a hierarchy structure based on the weightage for each feature. This study gave equal weightage to all parameters to calculate an index.

The index formula (Albacete et al., 2015) used in the analysis is

$$Index_{Ch} = \frac{f_i}{\sum_i fi}$$

where f_i is the potential frequency of any feature within each ward number *i*. The values obtained were normalised to add or subtract dimensionless. Therefore, the overall index for each ward is calculated as follows:

$$Overall\ index_{Ch} = P_i + TC_i + Tr_i + Pa_i + PP_i + SS_i - CS_i$$

where

P_i is the population index for the ith ward number

TC_i is the transit centres' index for the ith ward number

Tr_i is the traffic index for the ith ward number

Pa_i is the parking index for the ith ward number

PP_i is the petrol pump index for the ith ward number

SS_i is the substation index for the ith ward number

CS_i is the existing charging station index for the ith ward number

A sample index value calculation for Ward 191 is shown in Annexure 2.

4.3.4. Index Calculation for the Base Year

The output map in Figure 12 shows that ward numbers 94, 110, 111, 24, and 6 have the most suitable charging locations based on the index. Ward numbers 7, 38, 41, 198, 160, 150, and 85 have the second most preferred locations. All potential wards have existing BESCOM substations. Capacity utilisation and requirement analysis need to be carried out further to understand the availability and need for new stations.

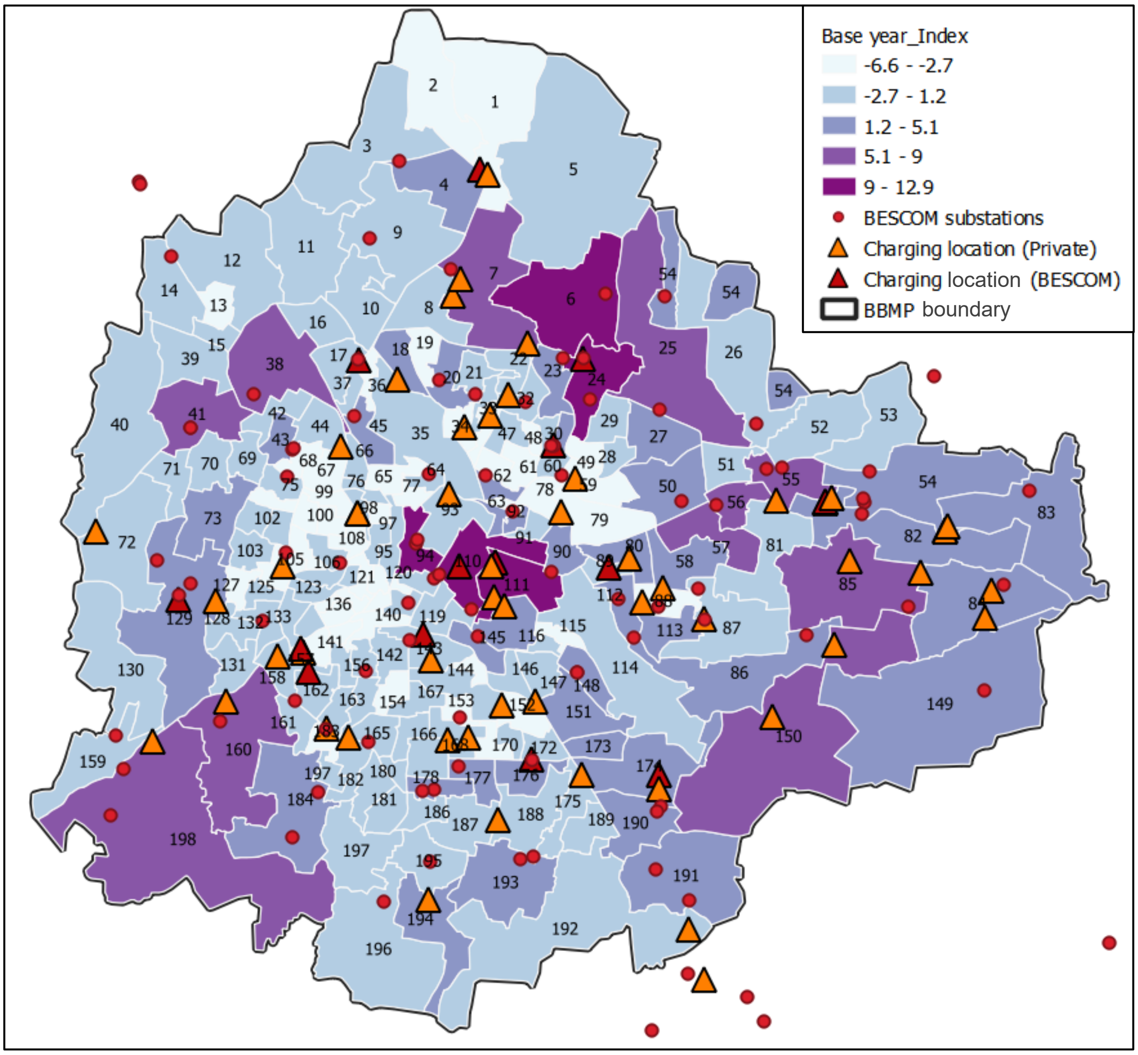


Figure 12: Ward-wise index values for the base year 2021

4.3.5. Index Calculation for the Horizon Year

Similarly, the index was calculated for the horizon year (2031) as well. The horizon year calculation assumed that all the existing infrastructure facilities (substations, transit centres, parking locations, etc.) would be available as such and traffic conditions would follow a similar trend to the base year. Also, a few potential corridors (e.g., the metro, light rail transit, and commuter rail) and multimodal hubs were added according to the proposed Master Plan. Similarly, proposed substations were added to the existing substation layer. The index calculation formula remains the same. The output map is shown in Figure 13. The graph infers that more peripheral areas are becoming suitable for installing charging infrastructure. Mostly, the potential wards have existing or proposed BESCOM substations. Capacity utilisation and requirement analysis need to be carried out further to understand the availability and need for new stations. The list of potential locations for public charging stations is given in Annexure 3.

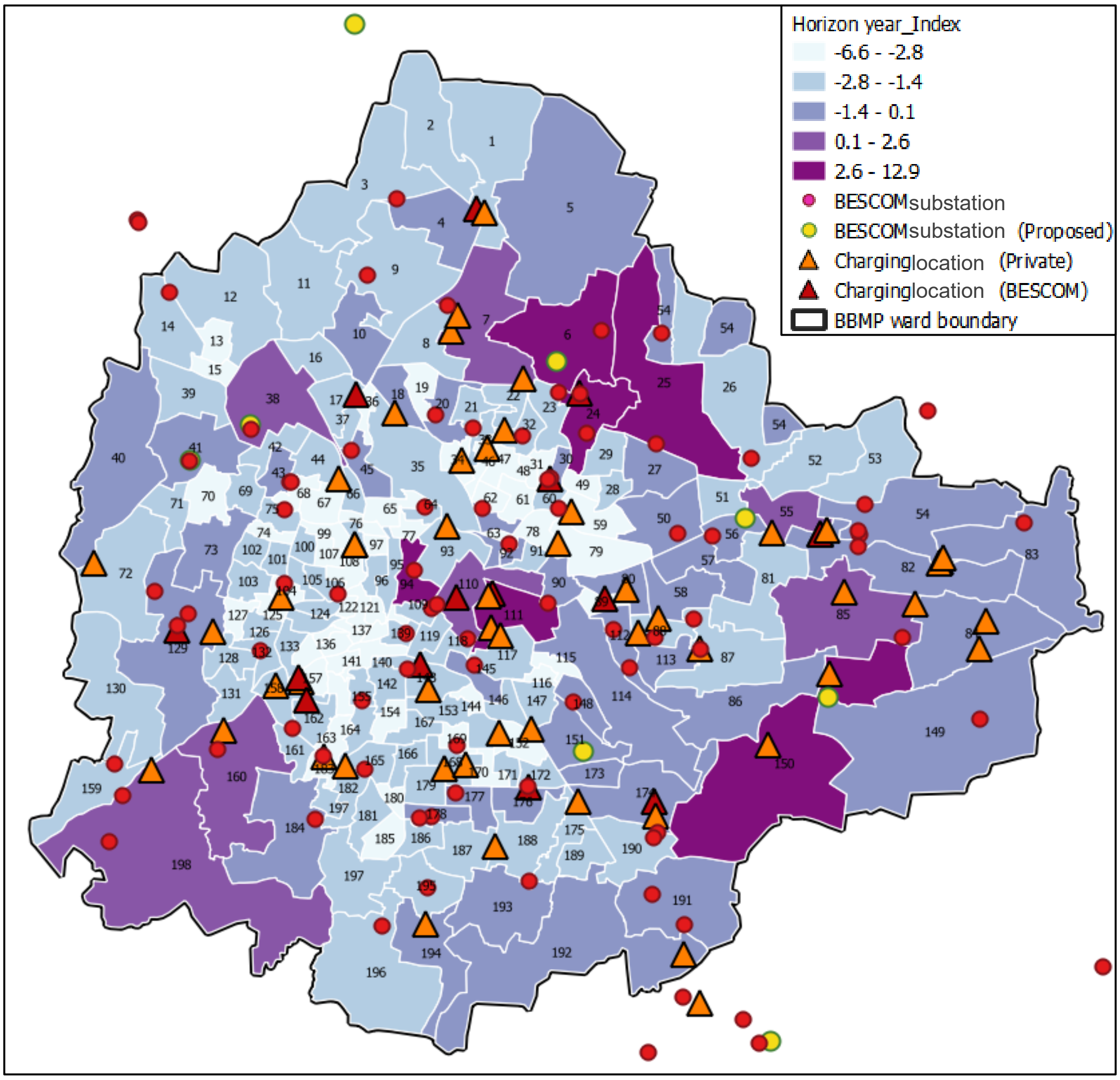


Figure 13: Ward-wise index value for the horizon year 2031

4.4. Scenario Analysis

The study also aims at developing scenarios for EV penetration for the horizon year 2031. Based on data from the transport department of Karnataka, registered vehicles for the year 2031 have been estimated. Here, we assume that the growth rate will remain the same until 2031. The details of the number of vehicles are given in Annexure 1. For the study, two EVs from Mahindra (e2O and Verito) and one internal combustion engine (ICE) vehicle from Toyota (Etios) were considered. The vehicle types considered for the different segments are given in Table 8. Further, based on literature, a percentage of scrapping has been assumed to estimate the on-road vehicles by 2031.

Table 1: Vehicle category-wise growth rate and scrapping

Vehicle Category	Growth Rate (%)	Scrapping (%)	2021	2031
Autorickshaws	7.1	31*	3,03,312	60,2261
Cabs	7.37	15*	1,81,983	3,70,562
Buses	0.14	20**	6,170	6,261

*(Transport Department, Karnataka, 2020)

***Calculated based on the BMTC scrapping percentage*

The following three scenarios have been developed based on the literature review and policy landscape:

- Business-as-usual scenario (BAU; S1): 2% EV penetration, which is the current scenario
- Pragmatic scenario (S2): 30% EV penetration as per India's EV sales target (Clean Energy Ministerial, 2019)
- Best-case scenario (S3): 100% EV penetration as per the initial policy target (Commerce and Industries Department, GoK, 2017)

Table 2 shows the number of on-road EVs in Bengaluru by 2030 based on different EV penetration scenarios.

Table 2: Scenario-wise CO_2 emission reduction potential

Scenario	EV Penetration	EV Autorickshaws	EV Cabs	EV Buses	Local CO_2 Emission* (KT)
S1	2%	8,158	6,264	125	4,052
S2	30%	1,22,371	93,953	1,878	2,894
S3	100%	4,07,902	31,3178	6,261	0

*Tailpipe emissions from vehicles

Compared to the business-as-usual scenario (S1), the pragmatic scenario (S2) shows 1,158 KT reduction and S3 shows 4,052 KT reduction in local (tailpipe) CO2 emissions. The emission for the horizon year is zero because we considered only tailpipe emissions for this study. The tailpipe emission of EVs is zero. The CO_2 emission share is estimated to be 45% for autorickshaws, 49% for cabs, and 6% for buses.

4.4.1. Public Chargers and Energy Requirement

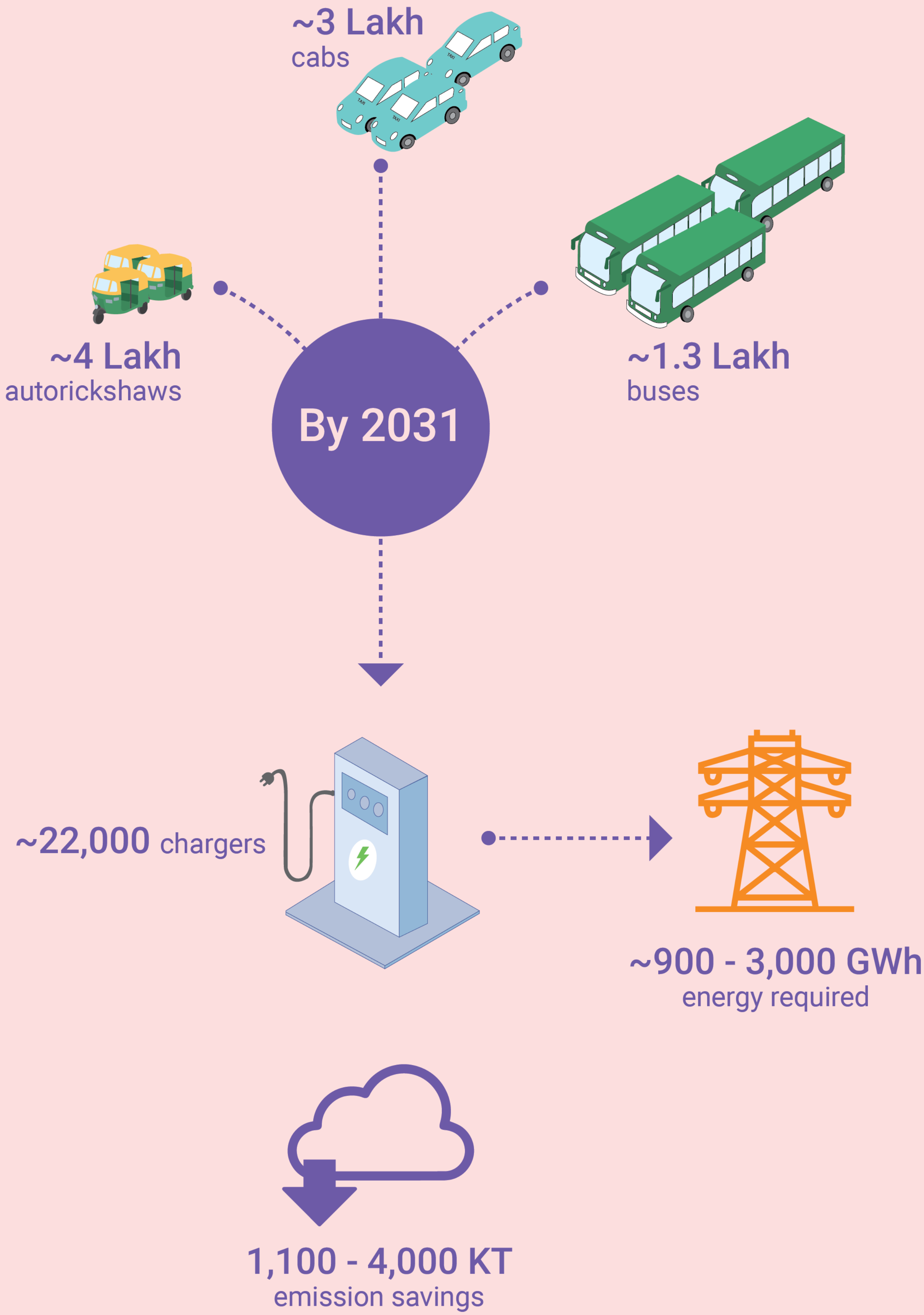
World EV leaders such as China and Europe have the best ratio of EVs to chargers of 2:1. The European Union suggests having one charger for 10 vehicles as a standard. Table 3 shows the number of chargers and the energy required for the estimated number of EVs scenario-wise.

By 2030, we estimate that the number of vehicles in the three segments considered in the study shall reach ~7.27 lakh. Achieving the pragmatic scenario can reduce the emissions to

50% compared to business as usual. However, the electricity requirement for the pragmatic scenario will increase by 839 GWh over the business-as-usual scenario, and this energy will mainly come from coal, given the current energy mix. Hence, to reduce well-to-wheel emissions, we need to power the EVs by renewable energy.

Table 3: Number of chargers and energy requirement for EVs scenario-wise

Scenario	S1	S2	S3
Number of EVs	14,547	2,18,202	7,27,341
CO_2 emissions	4,052	2,894	0
Number of chargers required	1,455	21,820	72,734
Energy required (MWh)	60,000	8,99,000	29,97,000


~3 Lakh
cabs
~4 Lakh
autorickshaws
~1.3 Lakh
buses
By 2031
~22,000 chargers
~900 - 3,000 GWh
energy required
1,100 - 4,000 KT
emission savings

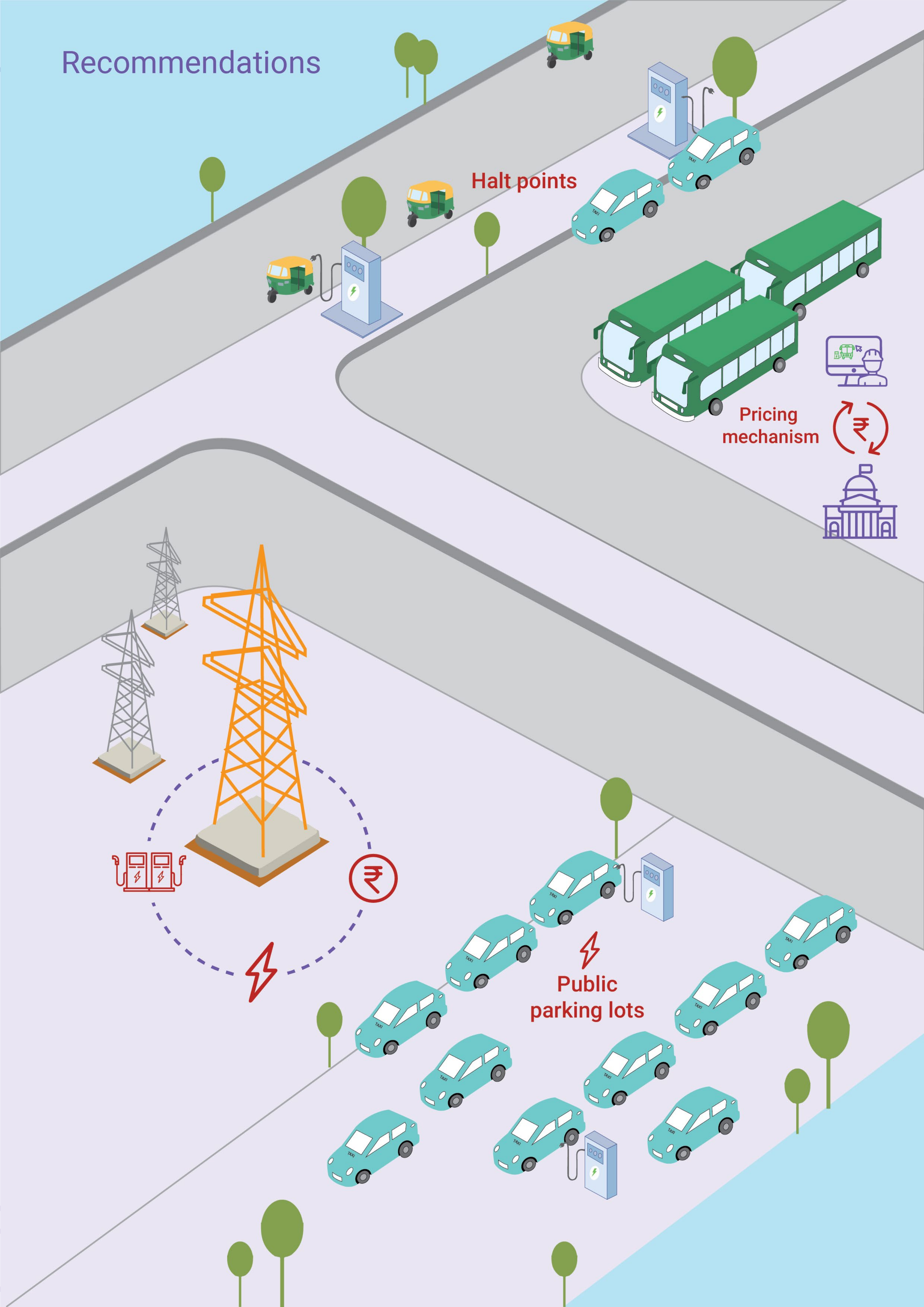
5. Conclusions

- Bengaluru is estimated to have ~4 lakh autorickshaws, ~3 lakh cabs, and 1.3 lakh buses by 2031, of which 6.3K could be city buses (based on the current growth rate). Assuming 30% EV penetration, ~22K chargers of different types and capacities would be required in the city.
- For the pragmatic scenario (S2), the energy requirement for charging EVs in the PT and IPT segments is estimated to be around ~900 GWh. For 100% penetration (S3), it is 3,000 GWh.
- Considering the 2030 BESCOM energy requirement estimate for Bengaluru, the total energy requirement for S2 is around 4.5% and S3 is around 15%.
- Carbon emission savings for S3 is estimated to be 4,000 KT. For S2, it is estimated to be around 1,100 KT.
- Most of the identified potential wards have high-density corridors, existing/proposed substations, public parking lots, and fuel pumps. Such wards could be prioritised for constructing public charging stations.
- Many BESCOM charging stations are currently installed on government land, making them largely inaccessible to the PT and IPT segments.
- The framework can be beneficial in identifying appropriate locations for charging stations and overcoming a majority of the challenges faced by existing charging stations.

6. Challenges

Apart from location identification, utilities and government entities face a few more challenges in setting up public charging stations. Low utilisation, high upfront cost, and the lack of a revenue model are three major challenges. The level of EV penetration and the lack of awareness are factors that affect the utilisation of public charging stations today. Also, setting up charging infrastructure at a city level is expensive at the moment. The cost of one charger ranges from INR 1 lakh to INR 5 lakh. To deal with these concerns, a suitable revenue model needs to be explored, which will achieve a balance between investment and revenue.

Recommendations



7. Recommendations

- Considering the current rate of EV adoption, a phased approach in setting up public charging stations would be advisable to reduce the upfront cost and tackle the issue of low utilisation.

- A pricing mechanism needs to be worked out between the government and fleet operators to utilise the land available, encourage private partners to set up charging infrastructure, and help electricity utilities to recover the investment cost in a stipulated time frame.

  - There could be a collaboration between local authorities and electricity utilities for the optimum utilisation of resources, such as land and grid infrastructure, to bring down the upfront cost and maximise utilisation.

- For new grid infrastructure development, demand from various EV segments under different adoption rate scenarios, the existing capacity of the grid, and available infrastructure could be considered.

- Feasible public–private partnership models and regulatory mechanisms could be worked out by utility providers, considering the role of various stakeholders in the EV ecosystem.

- Trip-generating and trip-attracting wards and wards with public parking lots could be prioritised for setting up public charging stations.

- Setting up EV charging stations in existing public parking lots could reduce the cost burden of the Government for land acquisitions.

- Tie-ups with public and intermediate public transport entities could increase the utilisation of public EV charging stations.

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9. Annexures

Annexure 1

Population and Vehicle Population Projection

Table 4: Population projection (sample calculation for 5 wards)

Ward Name	Ward No.	POP 2001	POP 2011	Growth Rate (%)	POP 2021	POP 2031
Chowdeswari Ward	2	19,626	36,602	86	68,080	1,26,628
Malleswaram	45	36,321	34,196	-6	32,144	30,216
Gayatri Nagar	76	35,389	33,236	-7	30,909	28,746
Radhakrishna Temple Ward	18	26,211	35,122	33	46,712	62,127
Sanjay Nagar	19	24,178	32,491	34	43,538	58,341

Vehicle Population Projection

Table 5: Total registered vehicle projection

Sl No.	Vehicle Category	2018	2020	2021	2031	Growth Rate
1	Autorickshaws	2,52,271	2,89,391	3,09,938	6,15,417	7.1
2	Cabs	1,70,381	1,96,416	2,10,892	4,29,427	7.37
3	Buses	1,05,596	1,16,877	1,22,966	2,04,341	5.21

Table 6: On-road vehicles projection

Sl No.	Vehicle Category	Registered Vehicles (%)	2021	2031
1	Autorickshaws	68	2,09,916	4,16,812
2	Cabs	85	1,78,234	3,62,928
3	Buses	80	98,373	1,63,473

Table 7: Estimated EVs on the road

Sl No.	Vehicle Category	S1 (2%)	S2 (30%)	S3 (100%)
1	Autorickshaws	8,158	1,22,371	4,07,902
2	Cabs	6,264	93,953	3,13,178
3	Buses	2,757	41,352	1,37,842

Vehicle Specification

Table 8: Electric vehicle category-wise technical specifications considered in the study

Sl No.	Vehicle Type	Vehicle Name	Seating	Range (km)	Battery Type	Battery Capacity	Time to Full Charge
1.	Three-wheelers (autorickshaws)	Mahindra Treo	D + 3	130	Li-ion	7.37 kWh	4 hours
2.	Three-wheelers (rickshaw)	Mahindra Treo	D + 4	85	Li-ion	3.69 kWh	3 hours
3.	Three-wheelers (autorickshaws)	Piaggio	D + 3	68	Li-ion	4.5 kWh	NA (swapping)
4.	Four-wheelers	Mahindra e20 plus	D + 3	110–140	Li-ion	280 Ah, 210 Ah	6–8 hours 1hr 35min (fast)
5.	Four-wheelers	Mahindra eVerito	D + 4	110	Li-ion	21.2 kWh	8 hours 1 hr 40 min (fast)

Table 9: Fuel CO_2 emission factors

Sl No.	Fuel	CO2 emission (kg/lit)
1	Petrol	2.31 ('India GHG Program - India Specific Road Transport Emission Factors', 2015)
2	Diesel	2.68 ('India GHG Program - India Specific Road Transport Emission Factors', 2015)
3	CNG	3.14 (Calculation of CO2 Emissions, n.d.)

Annexure 2

Index Value Calculation

Consider Ward 191. The number of features available in the given ward is shown below:

Table 10: Ward features and their quantity

Sr No.	Ward Features	Quantity
1	Population (2021) of Ward 191	71,004
2	Number of metro stations	1
3	Number of bus stations	1
4	TTMC/depot	0
5	Substation	1
6	Charging location	0
7	High-density corridor and major junctions	0
8	Parking	0
9	Petrol pumps	1

Index calculated using the formula given in Equation 2:

$$Overall\ Index_{Ch} = P_i + TC_i + Tr_i + Pa_i + PP_i + SS_i - CS_i \text{ ---------------------} \quad 1$$

where P_i is calculated as

$$P_i = \frac{Population\ of\ ward\ i}{Total\ population} \text{ ---------------------------} \quad 2$$

$$P_{191} = \frac{71{,}004}{86{,}56{,}305} = 0.0082$$

The normalised index value becomes $P_{191} = 2.26$

Normalised value = (x- $\bar{x}$) / s;

where x = Population of ward i
$\bar{x}$ = Mean of total ward population
s = Standard deviation of total ward population

Similarly, TC_i is calculated as

$$TC_i = \frac{Total\ number\ of\ transit\ centers\ at\ ward\ i}{Total\ transit\ centers\ avaliable\ in\ the\ BBMP\ ward\ boundary} \text{ -----------------} \quad 3$$

$$TC_{191} = \frac{2}{164} = 0.012$$

The normalised index value becomes $TC_{191} = 0.90$

Likewise, the individual index value and overall index for Ward 191 are given in the table below:

Table 11: Index value calculation

Index Name	Index Calculated	Normalised Index
Population index	0.0082	2.26
Transit centre index	0.012	0.90
Traffic index	0.0	-1.02
Parking index	0.0	-0.48
Petrol pump index	0.0	-0.18
Substation index	0.023	2.335
Existing charging station index	0	-0.516
Overall index (summation of all values)		4.31

Annexure 3

List of Potential Locations

Table 12: Potential wards for the base year

Ward No.	Ward Name	Remarks
110, 111	Sampangiram Nagar, Shantala nagar	Have multiple private charging stations (CS)
24	HBR	Has one BESCOM CS; could have potential for more; substations are available
6	Thanisandra	Substation is available; capacity needs to be checked
7, 55, 56, 85, 160, 198	Bytaranyapura, Devasandra, A Narayanapura	Have one private CS; could have potential for more; substations are available
150	Bellanduru	Has one private CS; no substation
25, 94, 38, 41, 57	Horamavu, Gandhinagar, HMT, Peenya Industrial Area, CV Raman Nagar	No existing CS but substations are available

Table 13: Potential wards for the horizon year

Ward No.	Ward Name	Remarks
110,111	Sampangiram Nagar, Shantala nagar	Have multiple private CS
24	HBR	Has one BESCOM CS; could have potential for more; substations are available
6, 25, 94, 38	Thanisandra, Horamavu, Gandhinagar, HMT	Substation is available; a new station proposed in Ward 6.
7, 55, 56, 85, 160, 198	Bytaranyapura, Devasandra, A Narayanapura	Have one private CS; could have potential for more; substations are available
150	Bellanduru	Has one private CS; no substation
4, 82, 84, 129, 176, 194, 192	Yelahanka, Garudachar Palya, Hagadur, Jnanabharathi, BTM, Gottigere, Begur	Potential wards with one CS and existing substations; may have the potential for more charging stations
5, 10,18, 20,27, 40, 41, 54, 50,56,57,58,73, 83, 90, 92, 149, 86, 112,114,148, 151, 173, 177, 178, 184, 191,192, 193,	Jakkur, Dodda Bommasandra, Radha Krishna Temple, Ganga Nagar, Banaswadi, Dodda Bidarakallu, Peenya Indst. Area, Benniganahalli, Hudi, A Narayanapura, CV Raman Nagar, New Tippasandara, Kottegepalya, Kadugodi, Halasooru, Shivaji Nagar, Varthuru, Marathahalli, Domlur, Agara, Ejipura, Koramangala, Jakkasandra, J P Nagar, Sarakki, Uttarahalli, Singasandra, Begur, Arakere	No existing CS but substations are available

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