Identification of Optimum Location and Designing of Sustainable Charging stations for the electric vehicles – A case study of Coimbatore and LPA

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Abstract. To combat climate change and promote cleaner transportation, India aims to have at least 30% of new vehicle sales be electric by 2030. Achieving this goal requires a strong network of easily accessible charging stations. This project examines the potential of using renewable energy for these stations in Coimbatore and its surrounding area. It pinpoints the best locations and number of stations needed, providing a practical roadmap for their implementation. Additionally, it assesses green building concepts that meet LEED standards. This study explores green building concepts meeting LEED standards, providing a transferable methodology for sustainable EV infrastructure development in Coimbatore and beyond.

Keywords: Charging station, Coimbatore Local Planning Area, Electric mobility, Green rating, Optimum location.

1 Introduction

The 'Faster Adoption and Manufacturing of Electric and Hybrid Vehicles in India' (FAME) scheme is administered by the heavy industry department since April 2015 and it aims to bolster the adoption of Electric vehicles (EVs) in India. The provision of charging station infrastructure is the basic necessity to achieve this goal. Consumers' reluctance to embrace electric vehicles is primarily attributed to 'Range Anxiety,' a significant hurdle in the shift to electric mobility. FAME India, an integral part of the national electric mobility mission plan, aims to address this limitation by offering subsidies to encourage the adoption of electric vehicles. The initiative also focuses on building a robust charging infrastructure, planning to

ICSETPSD 2023, November 17-18, Coimbatore, India

DOI 10.4108/eai.17-11-2023.2342870

establish around 2700 charging stations in metros, smart cities, and hilly areas nationwide. This strategic approach ensures the availability of at least one charging station within a 3 km x 3 km grid, promoting widespread electric vehicle use.

The aim is to accelerate the transition to electric mobility, emphasizing accessibility, renewable energy integration, and efficient charging station placement based on the findings from the Coimbatore case study. Following are the objectives of the research.

- To establish an inclusive charging infrastructure, fostering the widespread acceptance of electric vehicles and aligning with the national electric mobility mission plan.
- To explore the possibilities of renewable energy sources for charging stations.
- To plan and design a typical electric charging station on a highway.
- To estimate the cost of the proposed typical charging station.

For FAME Scheme:

- Encourage faster adoption of electric and hybrid vehicles by way of providing an upfront purchase incentive for electric vehicles.
- Establish a necessary charging infrastructure for electric vehicles.

Yudhveer Kandukuri [1] developed a dynamic GIS model for optimum location identification of plug-in electric vehicle charging stations. Bálint Csonka and Csaba Csiszár [2] have determined the charging infrastructure location for electric vehicles and have elaborated a weighted multi-criteria method for both the national roads and districts.

2 Methodology

2.1 Study Area

Situated along the banks of the Noyyal River within the rain shadow region of the Western Ghats, Coimbatore experiences a consistently pleasant climate throughout the year. This is attributed to the refreshing breeze flowing through the 25 km long Palakkad gap. The city houses four special economic zones (SEZs) - Elcot SEZ, Chil SEZ, Span Venture SEZ, Aspen Mrs. A. Thilagam, Siddharth Krishna, Vasanth Ragul, Ragul Adithya, Rakshit, Dhanush Raghav, Dharani, and Babu S SEZ, with at least five more SEZs in the developmental pipeline. Coimbatore is also home to influential trade associations such as CODISSIA, COINDIA, and COJEWEL, representing a diverse range of industries. The city boasts over 25,000 small, medium, and large-scale industries. According to the 2011 census, Coimbatore's population was 24,83,363, with a projected population of 28,26,103 by 2030. The total number of vehicles in Coimbatore is expected to reach 12,02,315 by 2030, with 92 % of those falling into the two-wheeler segment. Thus, the provision of infrastructure for electric vehicle charging is critical. This project aims to provide the optimum location and number of charging stations for Coimbatore LPA which is sufficient to meet the needs of E-mobility in the future.

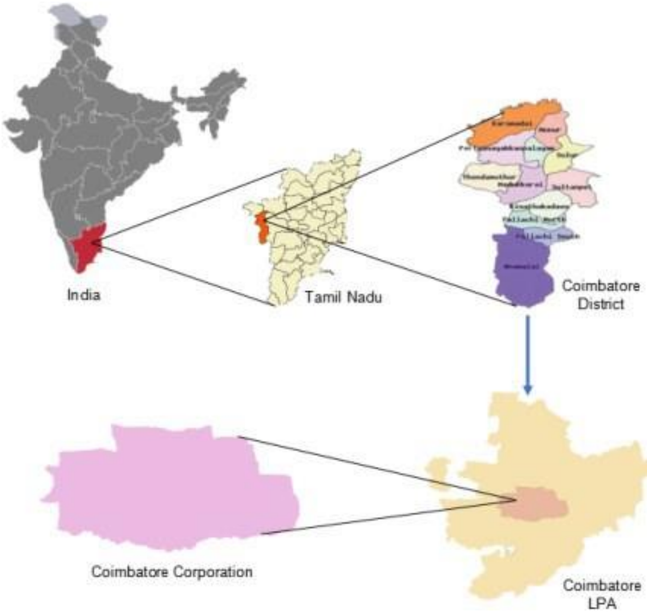

Fig. 1 Location map of the study area

2.2 Digitization and creation of map layers

Quantum Geographic Information System (QGIS) is an open-source Geographic Information System program that is used to capture, store, and manipulate various forms of geographical data and it also aids in the creation of graphical maps and their export.

Fig. 2 Digitized Coimbatore city map with major road network.

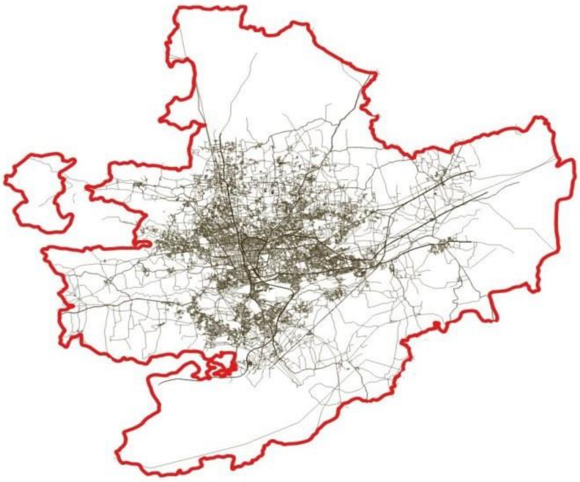

Fig. 3 Digitized Coimbatore LAP boundary with the road network.

The Coimbatore Corporation has four zones- North, East, West, and South which are further divided into multiple wards. First, each of the zone layers is overlaid over one another and then digitized. Secondly, these zones are digitized into Wards.

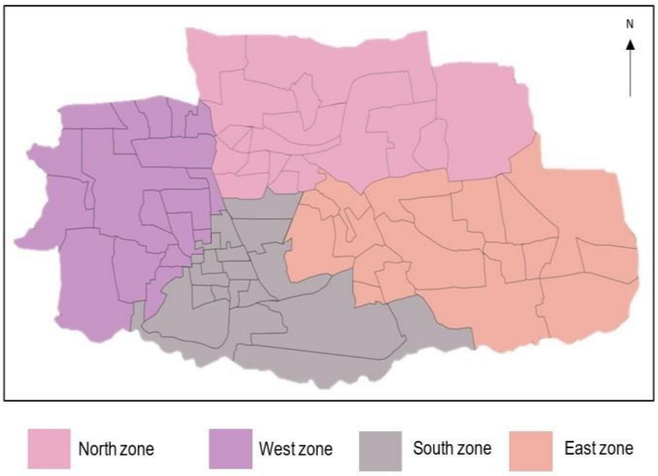

Fig. 4 Coimbatore city ward map

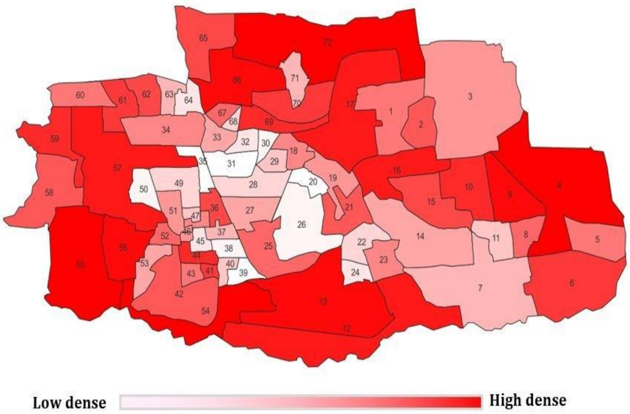

Fig. 5: City ward-wise population density map.

All of the aforementioned information about the existing petrol bunk is entered into the Petrol Bunk Layer's fields for the whole LPA region of Coimbatore. There are a total of 252 petrol bunks in Coimbatore LPA, out of which 99 petrol bunks are located in Coimbatore Corporation limit.

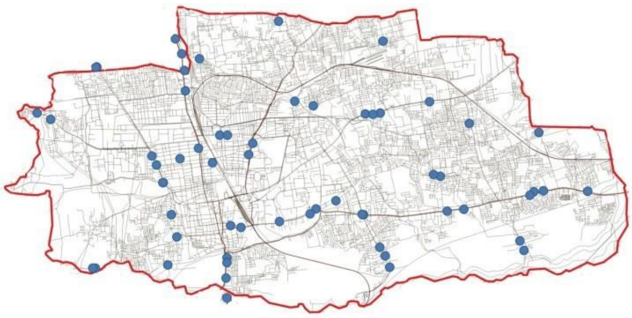

Fig. 6 Existing petrol bunks in the city corporation limit

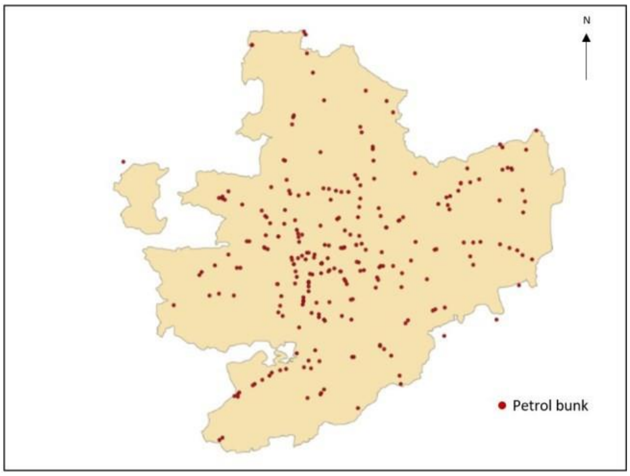

Fig. 7 Existing petrol bunks in LPA limit

2.3 Optimum location of EV charging stations

The optimum location of charging stations is found [3] based on the following three criteria - Points of interest, Grid of 3 km x 3 km, and Location of existing Petrol bunks.

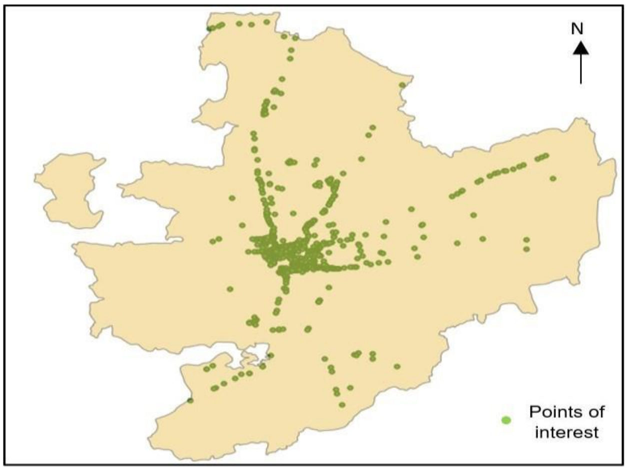

Fig. 8 Map of Coimbatore's points of interest.

The points of interest were located based on the following factors population density, parking availability, traffic volumes, commercial establishments, transit zones, and tourist places. These points of interest are converted into a heat map.

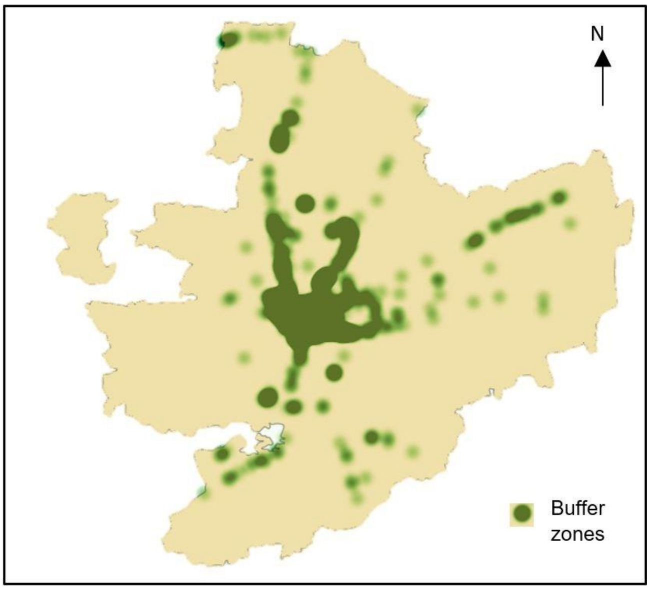

Fig. 9 Heat map based on points of interest.

According to the FAME II scheme, there should be at least one charging station in a grid of **3 km x 3 km** in metros, other million-plus cities, smart cities, and cities of Hilly states.
The heat map, existing petrol bunks, and grid are overlaid on each other. The heat map highlights important areas where charging stations should be located, with at least one charging station in each grid cell. As a result, new charging stations are proposed in significant areas based on the heat map, where there are no existing petrol bunks or when a grid has no existing petrol bunk in it.

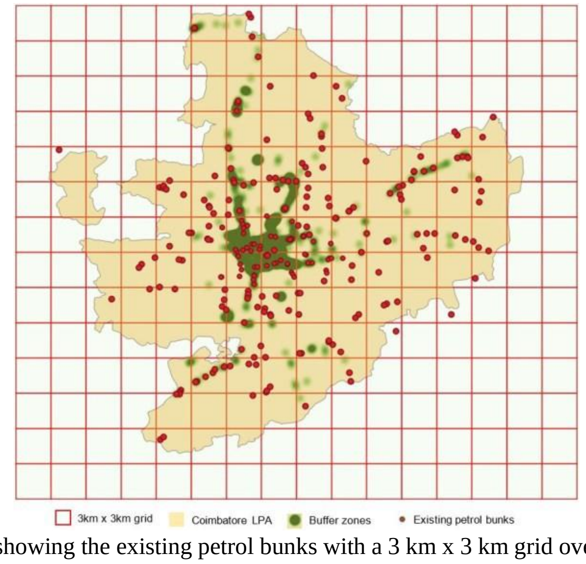

Fig. 10 Heat map showing the existing petrol bunks with a 3 km x 3 km grid over Coimbatore LPA.

The Coimbatore LPA's land use map has been added as a layer. The identified areas where charging stations need to be proposed are then checked on Google Earth to confirm if the land is designated for commercial purposes as per the Coimbatore City 2022 master plan.

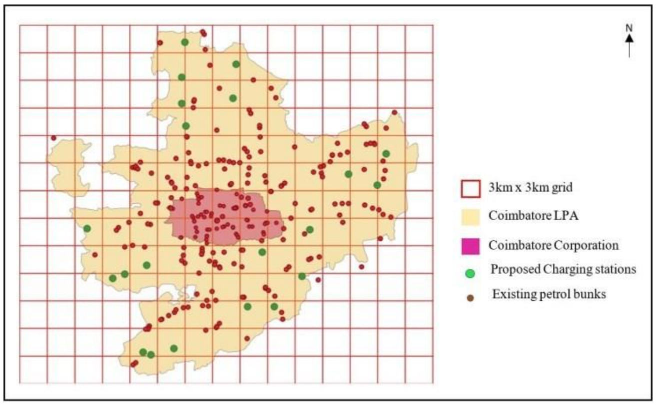

Fig. 11 Proposed charging stations.

The Minimum and Maximum distance between two charging stations in grids are maintained at 0.005 kilometers and 3.5 kilometers respectively. This procedure is carried out for all grid cells that cover the entire Coimbatore Local Planning Area

2.4 Analyzing future demand for charging stations in Coimbatore when the metro begins service

In 2010, India's central government planned 16 metro rail systems for 2-tier cities, including Coimbatore. In 2017, the railway minister stated that the Central Government is prepared to develop and fund a metro rail project in Coimbatore and the Tamil Nadu government unveiled a plan for a metro rail in Coimbatore which has been approved by the state government. In 2021, the Tamil Nadu government set aside Rs. 6,683 crore to execute the Coimbatore Metro Rail Project. In 2022, Finance Minister PTR.

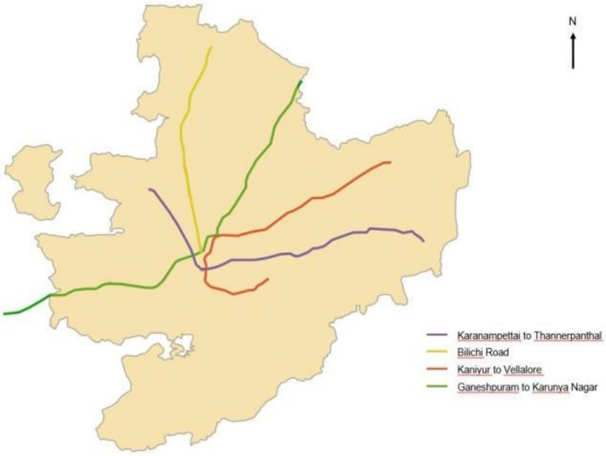

Fig. 12 Proposed metro rail corridor in Coimbatore LPA

Palanivel Thiagarajan announced the preparation of a detailed project report by CMRL, which is currently in the final stages; central government money will be given soon, and construction will begin at the earliest.

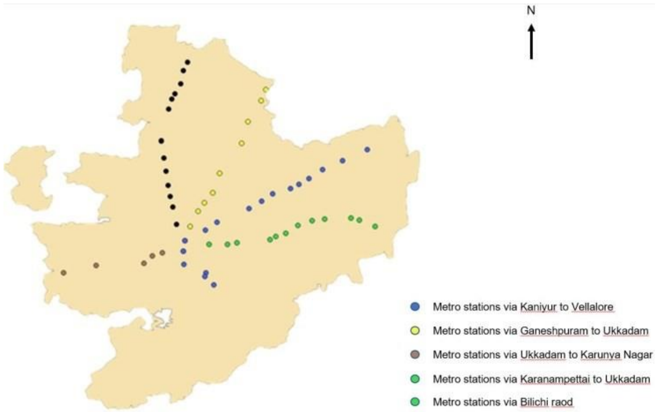

Fig. 13 Proposed stations along proposed metro corridors

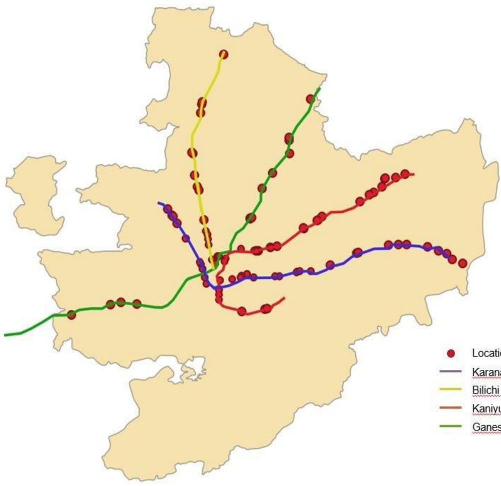

Fig. 14 Charging stations in the proposed metro rail corridors.

It has been confirmed that charging stations are intended along metro train routes. There are 117 charge places along the proposed metro rail lines, including 50 along the Avinashi and Pollachi road, 20 along Bilichi road, 15 along Sathyamangalam road, 24 along Trichy Road (Karanampettai to Ukkadam), and 8 along Siruvani road (Karunya Nagar to Ukkadam).

2.5 Estimation of EV Charging Demand

Conducting an assessment of electric vehicle (EV) charging demand serves various purposes in the planning of charging infrastructure. It provides essential input data for establishing targets regarding the quantity of public EV chargers. Additionally, this assessment informs the planning of locations for public charging infrastructure and aids in the analysis of electric grid capacity, identifying potential enhancements. The demand for EV charging at an urban or regional level is contingent upon factors such as per capita vehicle ownership rates, levels of EV penetration, and patterns of vehicle utilization [4]. First, the vehicles are

divided into four segments – 2 Wheelers, passenger and cargo 3 Wheelers, and personal and commercial 4-wheelers.

Table 1 Coimbatore LPA vehicle population.

Year	**2 W**	**3 W**	**4 W-Personal**	**4 W-Commercial**	**Total**
2014	1525831	22545	239954	16040	1804370
2015	1630079	23601	258514	16786	1928980
2019	1964121	22978	321064	14236	2322399
2020	2089140	24015	344441	15556	2473152

Table 2: Projection of vehicle production for 2030.

Year	**Annual growth**			
	2 W	**3 W**	**4 W-Personal**	**4 W-Commercial**
	5.88%	**5.57%**	**3%**	**15.80%**
2021	2211981	25352.64	354774.2	18013.85
2022	2342046	26764.78	365417.5	20860.04
2023	2479758	28255.58	376380	24155.92
2024	2625568	29829.41	387671.4	27972.56
2025	2779951	31490.91	399301.5	32392.22
2026	2943413	33244.95	411280.6	37510.19
2027	3116485	35096.7	423619	43436.8
2028	3299735	37051.58	436327.6	50299.82
2029	3493759	39115.36	449417.4	58247.19
2030	3699192	41294.08	462899.9	67450.24

Table 3: Estimated vehicle population for Coimbatore LPA**.**

Year	E2	E3	E4-Personal	E4-Commercial	Total
2025	2678879	24276.8	459051	13750.4	3175957
2030	3449723	24919.6	614598	12686.5	4101927

Table 4: Electric vehicles penetration rate.

Vehicle segment	**E2**	**E3**	**E4 - personal**	**E4-commercial**
Penetration rate	30%	70%	15%	30%

Table 5: Total number of EVs in Coimbatore LPA in 2030.

S. No	**Vehicle segments**	**Annual growth rate**	**EV penetration rate 2030**	**Total number of EVs in 2030**

1	E 2W	5.88%	30%	317074
2	E 3W	5.57%	70%	8259
3	E car personal	3.00%	15%	19839
4	E car commercial	15.80%	30%	5782

Figure 15 shows the number of vehicles in each segment and their respective total charging demand in kilowatt-hours. This signifies that the Electric two-wheeler segment forms 90.34% of total electric vehicles in 2030 and takes up 64.5% of total charging demand in 2030 in Coimbatore LPA.

Table 6: Total daily charging demand demand in Coimbatore LPA in 2030.

S. No	Vehicle segments	Daily Kms driven	Driving range per full charge (km)	Battery capacity (kWh)	Daily charging demand (kWh)	Total daily charging demand in 2030 (kWh)
1	E 2W	40	80	2.5	1.25	396342
2	E 3W	120	100	7	8.4	69375.6
3	E car personal	40	312	30.2	4	79356
4	E car commercial	100	181	21.2	12	69384

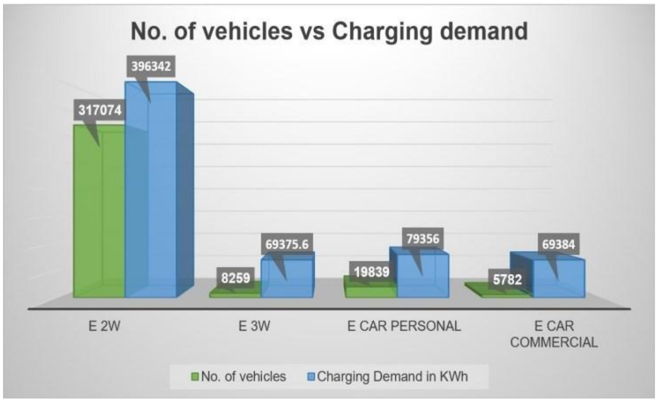

Fig. 15 Number of vehicles Vs charging demand.

2.6 Exploring Solar power as a Renewable Energy Source

Solar panels are a better renewable energy source since the petrol bunk canopy can be converted into a solar panel carrier. The rooftop space for the existing fuel bunk is measured individually. To locate petrol bunks and measure the rooftop area, Google Maps and Google Earth [5] are utilized, with the latter being saved as a layer in QGIS software.

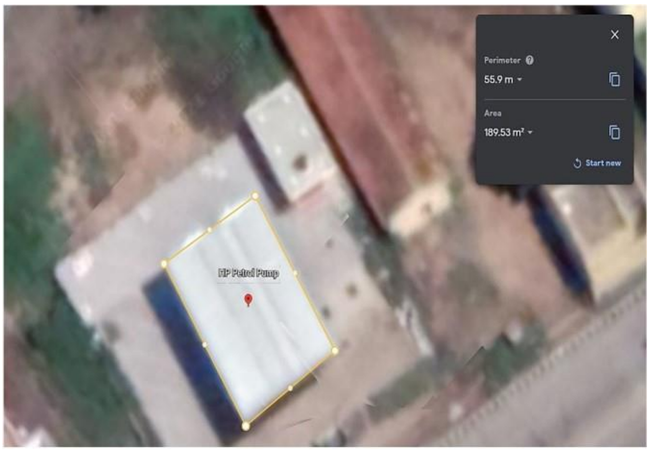

Fig. 16 Measuring roof area in Google Earth.

Table 7: Roof area of existing petrol bunks.

S. No	Company Name	Total Area in m²
1	Hindustan Petroleum	16965
2	Essar	3743
3	Bharat Petroleum	25540
4	Indian Oil	21342
5	Others	2881
6	**Total**	**71017**

Assuming that solar panels will cover at least 75% of the roof area i.e., 53262 m². Total energy supply from solar panels is 1,50,000 kWh. This covers 24.41 % of the total charging demand of electric vehicles in 2030 in Coimbatore LPA.

2.7 Architectural Planning Aspects of Typical Charging Station

A typical charging station has a layout and design that can be replicated in every charging station. The typical charging station that will be designed is along a highway.

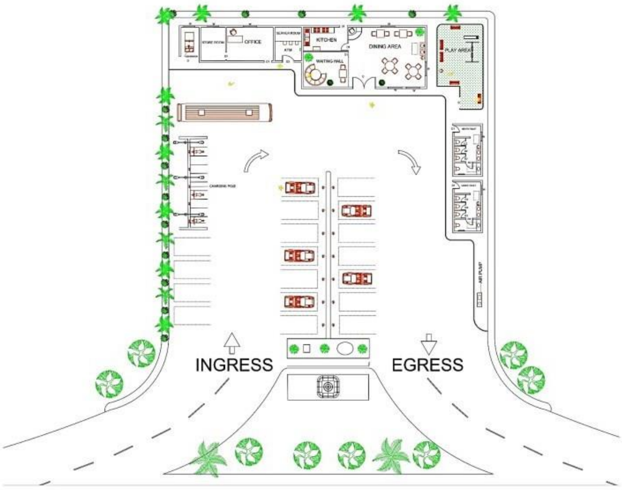

Fig. 17 Proposed plan of the typical charging station.

The proposed charging station includes facilities [6] such as an ATM, a generator room, Toilets, and a children's park.

Table 8 Area details.

S. No	Description	Area	
		Sq.ft	Sq.m
1	Café & Office building	2496.5	232
2	Toilets	598	55.55
3	Children Park	655	60.85
4	Parking lot for charging	3010	279.64

The comprehensive 3D model of the typical charging station is developed using Sketchup [7].

Fig. 18 Birds-eye view of the proposed charging station.

Fig. 19 3D   Front view of the proposed charging station.

Fig. 20 3D Comprehensive rendered model of the proposed charging station with solar panel.

Fig. 21 3D Comprehensive Rendered View of the Charging Station

Fig. 22 3D Rendered View of the Charging Station

Table 9 Number of solar panels in the proposed stations.

Location of panel	Number of 550-watt panels
Over parking canopy	70
Over Café & Office building	70
Over 2-wheeler parking shed	8
Total	**148**

The total energy output from the station is 384.8 kWh having 2.6 kWh as the output from the single 550-watt panel in a single day. Considering the maximum battery capacity of the car model as 30.2 kWh, the total number of E-cars that can be fully charged in the proposed charging station in a day is 12 EVs.

3 Cost Estimation

3.1 Cost of proposed charging station

Situated along the banks of the Noyyal River within the rain shadow region of the Western Ghats, Coimbatore experiences a consistently pleasant climate throughout the year. This is attributed to the refreshing breeze flowing through the 25 km long Palakkad gap. The city houses four special economic zones (SEZs) - Elcot SEZ, Chil SEZ, Span Venture SEZ, Aspen Mrs. A. Thilagam, Siddharth Krishna, Vasanth Ragul, Ragul Adithya, Rakshit, Dhanush Raghav, Dharani, and Babu S SEZ,

As the proposed structural plan may vary in years depending on personal demands, in this study detailed estimation is questionable; therefore, one of the approximate estimation methods – the plinth area method is made used by taking into account the actual cost in Coimbatore.

Table 10: Abstract of approximate estimation of the proposed charging station.

S. No	Description	Cost (Rs.)
1	Construction of Café and office building including labor charges, sanitary, electrical fittings & water supply for size of 2,497 sqft	59,05,596
2	Construction of toilet including labor charges, sanitary fitting, water supply for size of 600 sqft	14,35,200
3	Laying of Paver blocks using 60 mm thick block on kerb area for size of 1,808 sqft	1,77,184
4	Laying of Paver block using 80 mm thick block on parking area of size 15,886 sqft	17,79,232
5	Installation of twenty feet high mild steel canopy over vehicle charging area of size 3,010 sqft	19,60,000
6	Laying of lawn grass for play area of size 655 sqft	23,940
7	Installation of 19 Electric vehicle charging modules	1,75,90,000
8	Installation of 148 solar panels of size 1.7 m² each	53,28,000
9	**Total**	**3,41,99,152**

The estimated approximate cost for constructing the proposed typical charging station is Rs. 3,41,99,152 (Three crores Forty-one Lakhs Ninety-Nine Thousand One Hundred and Fifty-two), excluding land cost.

3.2 Cost comparison between solar power and electric grid sources

To obtain the percentage of charging cost that can be saved while adopting the solar power method, a comparison table is prepared.

Table 11: Charging cost comparison.

S. No	Description	Car 4-wheeler		Bike 2-wheeler	
1	Battery capacity	30.2 kWh		17.5 kWh	
2	Cost charged per unit (Rs.)	Solar power	Electric grid	Solar power	Electric grid
		5	9	5	9
3	Cost charged for full charge (Rs.)	151	271.8	87.5	157.5

4 Green Building Rate

The goal of a green building design is to

- Reduce non-renewable resource demand,
- Increase the efficiency of these resources while in use,
- Optimize the reuse, recycling, and usage of renewable resources.

4.1 Green building rating of proposed typical charging station

Leadership in Energy and Environmental Design (LEED) [9] is a consensus-based building grading system based on the usage of current building technologies. As in accordance with the LEED rating system, the proposed charging station has been evaluated.

LEED categories and credits:

- Location and transportation – 16 credits
- Sustainable sites – 10 credits
- Water efficiency - 11 credits
- Energy and atmosphere - 33 credits
- Materials and resources - 13 credits
- Indoor environmental quality - 16 credits
- Integrative process - 01 credit
- Innovation - 06 credits

Regional priority - 4 credits

Table 12: Rating categories in LEED

Categories	Platinum	Gold	Silver	Certified
Points	80+	60-79	50-59	40-49

Table 13: Green building rating for the typical charging station.

Criteria	Points	Sub Criteria	Points
Integrative process	0 / 1	Integrative process	0 / 1
Location	15 /	Sensitive Land Protection	1 / 1

and transportation	16	High Priority Site and equitable Development	2 / 2
		Surrounding Density and diverse Uses	5 / 5
		Access to Quality Transit	5 / 5
		Bicycle Facilities	0 / 1
		Reduced Parking Footprint	1 / 1
		Electric vehicles	1 / 1
Sustainable sites	6 / 10	Site Assessment	1 / 1
		Protect or Restore Habitat	0 / 2
		Open Spaces	1 / 1
		Rainwater Management	3 / 3
		Heat Island Reduction	0 / 2
		Light Pollution Reduction	1 / 1
Water efficiency	4 / 11	Outdoor Water Use Reduction	2 / 2
		Indoor Water Use Reduction	0 / 6
		Optimize Process Water Use	2 / 2
		Water metering	0 / 1
Energy & atmosphere	26 / 33	Optimize Energy Performance	18 / 18
		Enhanced Commissioning	0/ 6
		Advanced Energy Metering	1 / 1
		Renewable Energy	5 / 5
		Enhanced Refrigerant Management	0 / 1
		Grid Harmonization	2 / 2
Energy & atmosphere	26 / 33	Optimize Energy Performance	18 / 18
		Enhanced Commissioning	0/ 6
		Advanced Energy Metering	1 / 1
		Renewable Energy	5 / 5
		Enhanced Refrigerant Management	0 / 1
		Grid Harmonization	2 / 2
Materials & resources	7 / 13	Environmental Product Declarations	0 / 2
		Building life cycle impact reduction	5 / 5
		Sourcing of Raw Materials	2 / 2
		Material Ingredients	0 / 2
		Construction and Demolition Waste Management	0 / 2
Indoor environmental quality	9 / 16	Enhanced Indoor Air Quality Strategies	2 / 2
		Low emitting materials	0 / 3
		Construction indoor air quality management plan	0 / 1
		Indoor air quality assessment	0 / 2
		Thermal Comfort	1 / 1
		Interior Lighting	2 / 2
		Acoustic performance	0 / 1
		Daylight	3 / 3
		Quality Views	1 / 1
Innovation	5 / 6	Innovation in design	5 / 5
		LEED Accredited Professional	0 / 1
Regional priority credits	4 / 4	Regional Priority Specific Credits	4 / 4

Total points acquired	76 /110

The proposed typical charging station has a GOLD green building rating of 76 out of 110 as per the LEED Scorecard.

5 Results and Discussion

Leadership in Energy and Environmental Design (LEED) [9] is a consensus-based building grading system based on the usage of current building technologies. As in accordance with the LEED rating system, the proposed.

5.1 Discussion on digitizing the study area

Figure 1 shows the study area considered for the study - the Coimbatore Corporation and Local Planning Area boundary digitized by tracing the raster image of corresponding maps which had been georeferenced using freehand raster tool from plugins in QGIS. The road networks of the study area are digitized as shown in Figure 2 and Figure 3. The ward map of Coimbatore Corporation is digitized as shown in Figure 4. The ward-wise population density map of Coimbatore Corporation is digitized as shown in Figure 5.

5.2 Discussion on locating the existing petrol bunks

To locate petrol bunks in the study area, the base map is obtained from Google Maps. Google Maps are used to search for petrol bunks in the study area. Ground truth verification of the existing petrol bunk is examined. Figure 6 and Figure 7 show the existing petrol bunks in Coimbatore Corporation and LPA respectively.

5.3 Discussion on identifying the optimal location for electric charging stations

The methodology for the optimum location of the charging station is followed as

1. Importing GIS layer of Points of interest i.e., Population density, Parking availability, Traffic volumes, Commercial establishments, Transit zones, and Tourist places in Coimbatore LPA as shown in Figure 6, and creating a Heat map out of it where weightage is assigned based on how close each point is.
2. Creating a GIS layer consisting of all existing petrol bunks in Coimbatore LPA.
3. Creating a 3km X 3km grid over the LPA as per the FAME-INDIA scheme.
4. Overlapping all the above-created layers and proposing new charging stations manually as mentioned below.
   a. The land use map of the Coimbatore LPA is added as a layer.
   b. The areas in which charging stations needed to be proposed are identified.
   c. The Land Use of that particular grid is studied and commercial, public, and semipublic land are considered for proposing new charging stations.

5.4 Discussion on the estimation of demand for public EV charging station

Table I, Table II, and Table III show the projection of EVs for the year 2030 in Coimbatore LPA using the average annual growth rate percentage. The target EV penetration rates for electric vehicles in Coimbatore LPA in 2030 in each vehicle classification are shown in Table IV. Table V shows the projected total number of EVs in Coimbatore LPA in 2030. Based on the average battery capacity and the driving range of each vehicle classification, the daily energy requirement for EV charging is calculated as shown in Table VI which is depicted in Figure 16.

5.5 Discussion on measuring roof area for Solar panel installation

The roof area of each existing petrol bunk is added in the attribute table of QGIS and the entire data for 252 petrol bunks is consolidated in Table VII.

5.6 Discussion on developing a 2D plan of the typical charging station

The amenities and facilities of a charging station and their locations are thoroughly addressed before beginning to design a 2D plan for the charging station. Apart from office space and charging slots, a typical charging station includes [7] a restaurant/café, restroom, ATM, and lounge. Figure 15 shows a bubble diagram that consists of roughly drawn bubbles (representing spaces) connected by solid lines, broken lines, wavy lines, etc. to specify the type of relationship between the spaces. The bubble diagram's main aim is to assist us in translating the program into a strategy. Planning of the charging station is performed using AutoCAD as shown in Figure 18, to arrange the various components systematically to form a meaningful and homogeneous structure to meet its functional purpose [6]. The area details are mentioned in Table VIII.

5.7 Discussion on the approximate estimation of the proposed charging station and cost comparison

An approximate estimation is a rough cost estimation prepared to obtain an approximate cost in a short time. As the proposed structural plan may vary in years depending on personal demands, detailed estimation is questionable; therefore, an approximate estimation method – the Plinth area method [8] is adopted for the estimation which is prepared on the basis of the plinth area of the building which is the area covered by external dimensions of building at the floor level. The plinth area rate of building is the cost of a similar building with specifications in that locality. The real-time costs are obtained from actual engineers and contractors in Coimbatore viz., Akshaya pavers, Coimbatore, Site Engineers, Coimbatore, Infinite structure Private Ltd, Vikram Solar Ltd.

The calculation for finding the cost of electric power from solar panels per unit

Cost of total units obtained per day = (total cost of installing solar panel) / (life span of solar panels in days)

= 53,28,000 / 9125

= Rs.583.9

Cost of 1 unit of power from solar panel = 584 / 384.8

= Rs. 1.517 + maintenance cost

Maintenance cost of solar panel per day for 1 unit of power

= 3000 / 365

= Rs. 2.74

Cost of 1 unit of power from solar panel = 1.517 + 2.74

= 4.25 ≈ Rs. 5 (with profit of 75 paise per unit)

The cost of charging an EV for 1 unit using an electric grid is Rs. 9

6 Conclusion

The Coimbatore Corporation and LPA is digitized manually using QGIS software. The existing 252 petrol bunks in Coimbatore LPA are located and their roof area of 71017 m² is measured.

The total electric vehicles- two-wheelers, three-wheelers, and four-wheelers in Coimbatore LPA by 2030 are estimated at 3,50,954 and the total daily charging demand for these EVs in 2030 is estimated as 6,14,458 kWh out of which 24.41 % of energy requirement can be met by installing rooftop solar panels in existing bunks.

The optimum number of 274 charging stations including 22 proposed charging stations and the location of such charging stations in Coimbatore LPA are identified. A. The minimum and maximum distance between any two EV charging stations in the grid is 0.05 km and 3.5 km respectively as per FAME India scheme 2019.

The typical sustainable charging station located on any highway is planned and a sustainable 3D model is developed.

Cost estimation of the designed typical charging station is calculated using the approximate cost estimation method. The total cost of the proposed charging station is calculated as Rs. 3,41,99,152 (Three crores Forty-one Lakhs Ninety-Nine Thousand One Hundred and Fifty-two) including amenities and facilities like a Children's Park, Café, ATM, and Toilet. Whereas the cost of a charging station in the Active method i.e., drawing electricity from the electric grid, is Rs. 2,88,71,152 (Two crores Eighty-eight Lakhs Seventy-One Thousand One Hundred and Fifty-two). The cost of charging by using a solar panel is Rs. 5 per kWh, whereas the cost for charging from an electric grid is Rs.9 per kWh. It is also found that solar energy saves Rs.4 per kWh of electricity in charging costs i.e., 44.5 % of the charging cost is saved.

The proposed typical charging station has a GOLD green building rating of 76 points out of 110 points as per LEED green building rating system scorecard. Hence the proposed charging station is a self-sustaining charging station.

The methodology adopted in this study to find the optimum location of charging stations can be used in different study areas in the future as well. The design of the typical highway charging station can be customized and used when designing a charging station at any place in the future as well.

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