science, engineering and health studies

Research Article

Science, Engineering and Health Studies
https://li01.tci-thaijo.org/index.php/sehs
ISSN (Online): 2630-0087

Sustainable planning for cities: Weaving e-infrastructure for green transportation in current city profile of Bhubaneswar, India

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***Received**: 14 June 2024*
***Revised**: 13 December 2024*
***Accepted**: 30 December 2024*
***Published**: 24 March 2026*

***Citation**:*
Prasad, S., Sarkar, S., & Kazmi, R. (2026). Sustainable planning for cities: Weaving e-infrastructure for green transportation in current city profile of Bhubaneswar, India. Science, Engineering and Health Studies, 20, 26020001.

ABSTRACT

Growing CO_2 emissions in the environment have significantly contributed to global warming. With the average global temperature increase from carbon concentration in the air, recording almost 1.5ºC (IPCC, 2023), governments across regions must shift to using electric vehicles (EVs) in the transportation sector. By 2050, greenhouse gas emissions from vehicles are expected to have reduced by 50%, according to the research (NRDC India, 2022). By 2030, Bhubaneswar, already designated as a “Smart City,” is envisioned as a green transportation hub in eastern India. This development highlights how the city adopts a holistic and inclusive approach to developing EV infrastructure through accessible and sustainable transportation. The demand for ownership of e-vehicles in Bhubaneswar has also increased substantially. The growth is hindered due to a lack of EV infrastructure, including charging stations, and a compromised distribution. The background of the study revolves around the fact that despite existing government policies at the national and state levels, there needs to be more methodology for providing e-vehicle charging infrastructure on the ground. Digitized geospatial analysis has been recommended to investigate infrastructure for charging various types of EVs based on their battery specifications and charging methods and to plan public charging infrastructure locations. The space allocation of the public infrastructure has been proposed based on road density and activity areas. For high-density roads, infrastructure provision has been proposed at every two km with six stations; for medium-density roads, every four km with four stations; and for low-density roads, every six km with two stations. The paper’s key findings include the establishment of a methodology to find the EV demand and e-infrastructure requirement for the baseline years of 2025 and 2030 to suffice EV needs for the city of Bhubaneswar, India. The proposal includes policy support and intelligent technology to weave a robust e-infrastructure across the city.

Keywords: emission; electric vehicle (EVs); EVs charging infrastructure; infrastructure allocation; geospatial analysis

1. INTRODUCTION

Problems of rising energy needs currently impregnate the automobile sector worldwide, such as the consumption of fossil fuels, environmental degradation, and climate change. The number of cars registered globally jumped from 200 million in 1960 to 1.475 billion in 2024 because of growing economies, populations, and an increasing need for customized vehicles among younger generations (Davis & Boundy, 2021). As against one billion cars on the planet in 2009, 363 million commercial vehicles and 1.06 billion cars are currently operating worldwide, totalling 1.42 billion. Approximately 12% of greenhouse gas emissions worldwide are caused by private automobiles. The transportation sector is responsible for approximately 22% of greenhouse gas emissions. Initiatives are being made to record reduced emissions from this segment (Mohamed et al., 2016). Much literature suggests that EV's CO2 emission is relatively much lower than an Internal combustion engine vehicle (ICEV) (Peng et al., 2021; Dai et al., 2022). A 1% increase in the sale of EVs in a city can reduce CO_2 emissions locally by 0.096% and by 0.087% in a nearby town. The government worldwide is stepping up regulations to encourage the deployment of electric vehicles (EVs), create charging infrastructure, and protect supply chains. Several nations are establishing guidelines to help them reach their goal. China has gradually reduced NEV (New Energy Vehicle) subsidies as sales increased to 16% in 2021, which tripled from 5% in 2020. China recently declared its intention to build enough charging stations by 2025 to accommodate 20 million NEVs. It also established rules for promoting EVs (IEA, 2022). In the United States, five hundred thousand public chargers and a 50% increase in electric vehicle sales by 2030 are among the first goals set by the federal government. The Infrastructure Investment and Jobs Act includes new funding packages totalling USD 7.5 billion for constructing "charging infrastructure" and USD 3 billion for supply chains for advanced batteries (IEA, 2022). European Union includes a plan to deploy new, compulsory charging infrastructure by 2035 both for "Light-Duty Vehicles (LDVs) and Heavy-Duty Vehicles," as well as a proposal to replace all current cars with 100% ZEVs (Zero-emission vehicles) before 2035 through its CO_2 emissions guideline (HDVs) (IEA, 2022).

Research indicates that the transportation industry is among the significant contributors to greenhouse gas emissions (Khan et al., 2022). Furthermore, the transportation segment's oil consumption is expected to increase by 54% by 2034 (Mishra et al., 2021). To lower greenhouse gas emissions from the transportation sector, "EVs substitute Conventional Internal Combustion Engines" (ICE). Utilizing EVs can reduce pollution while offering advantages, including noise reduction, decreased repair and maintenance costs, and lower operating expenses. By replacing traditional automobiles with electric ones, we can reduce our dependence on fossil fuels while addressing grave concerns regarding global warming and climate change (Deb, 2020; Zhao et al., 2023).

However, there are still many problems preventing the widespread adoption of EVs. The most recent widespread adoption of EVs has been hindered by several significant issues, including out-of-date battery technology, insufficient facilities for charging, a lack of public charging stations, improper station location, and disconnected infrastructure inside the charging stations. The biggest obstacles to electric vehicle adoption in India are interdependent infrastructure issues. The importance of accessible, reasonably priced charging infrastructure for EV adoption cannot be overstated. A practical charging network design and a sufficient supply of charging services are essential for fostering EV adoption, especially in their early growth stages (Shi et al., 2021). The lack of infrastructure for EV charging reduces demand and deters private-sector investment in EV charging. Amidst all of these, a recent survey by Earnest Young (2022), in their published report, states that 90% of Indian consumers for vehicles are willing to purchase EVs, with 40% showing interest in paying a premium for the purchase of EVs. The survey further claims that 70% of consumers are willing to shift to EVs as their next vehicle compared to the global average of 52% (Earnest Young, 2022).

Consequently, government incentives and public investments are required to establish a demand for infrastructure for electric vehicle charging (Khan et al., 2022). The Indian Government has already introduced Faster Adoption and Manufacturing of Electric Vehicles (FAME) to propose policies and incentives for EV adoptions. The Government of the State of Orissa, the capital of Bhubaneswar, has also incentivized different EV schemes. In this scheme, apart from the manufacturing sector capital subsidy, it has planned for a grant of approximately 66 USD to purchase charging equipment for the first twenty thousand private charging stations. Moreover, it has also provided a 25% capital subsidy to the selected energy operators for the first five hundred charging stations in the state. It has also emphasized consumer capital subsidies for two-wheelers, e-buses, and goods carriers (Earnest Young, 2022). India has approximately 70,000 petrol stations across 718 districts but only 300 electric vehicle charging stations countrywide (www.edifypath.com). Higher costs, a lack of technology, a shortage of skilled labour, the import of electric vehicle components and materials, and potential disruption in the auto industry also contribute to the cause of EV deployment. EV adoption would rise along with improved liveability if charging stations were planned judiciously. Planning the infrastructure for charging is a complex issue involving transport and distribution networks. By adding charging stations, the load demand of the utility grade rises, resulting in a higher peak demand and a smaller reserve margin. If a significant hub in the traffic network is not located near the power grid's strong points, planning a charging station becomes problematic. Considering all pertinent factors, this paper aims to investigate infrastructure planning for electric vehicle charging and interweaving within the city infrastructure. Bhubaneswar, a planned state capital of Odisha, has been taken up to demonstrate the objectives.

1.1 Need for study

While EV technology is gaining traction worldwide, India still needs to make a name for itself in this field. The Indian government has outlined the ambitious and desirable path for 100% electric vehicles. It offers a revolutionary approach to shared-connected-electric mobility, enabling 100% of public and 40% of private cars to transition to electric power by 2030 (SIAM, 2017). This vision needs enlargement to maximize the use of EVs and achieve a future of fully electric mobility.

The study area selected is Bhubaneswar, which has recorded a steady change in population over the last two decades, with a decadal growth rate of around 2–3%. With the city's current population recording around 12 lakhs, the PM 2.5 level in some regions shows a high concentration of 50–2000 tons/year/grid of 1 km by 1 km (https://www.aqi.in/in/dashboard/). Hence, the future stabilization of environmental pollution levels is required. As per the projection through RTO data, an increase in demand for ownership of E-vehicle has been observed and recorded up to almost 300%, including all segments over the last few years. This indicates a need for more consciousness of residents to challenge pollution in Bhubaneswar. However, the growth is hindered due to a lack of electric vehicle infrastructure, including charging stations, and a compromised distribution. This creates a hindrance to the development of EV purchases and promotions. It also analyses the obstacles associated with EV adoption and policies implemented to promote EVs. The background of the study revolves around the fact that despite existing government policies at the national and state levels, there needs to be more methodology for providing e-vehicle charging infrastructure on the ground. This study establishes a method for delivering e-vehicle charging infrastructure, taking a small pocket of 1 km X 1 km in the Central Business District of Bhubaneswar.

1.2 Objectives of the research

The study's objectives were to identify potential drivers of EV adoption, assist the government in formulating policy, and assist automakers in comprehending the demands and desires of their clientele. One issue the nation is currently facing is the requirement for extensive market research to accomplish this goal. Hence, the objectives of this research were:

[1] To research Bhubaneswar's infrastructure needs for electric vehicles.

[2] To identify the elements that should determine the best site for a public infrastructure facility for EV charging to service Bhubaneswar's transportation network.

[3] To calculate the trip success ratio model for allocating fast charging stations in the transportation network.

[4] To examine the effects of the EV charging station on the load distribution network.

[5] To evaluate the charging demand and to propose a scheme and economic plan for EV infrastructure for Bhubaneswar.

2. MATERIALS AND METHODS

The research is limited to EV charging infrastructure planning for Bhubaneswar. It limits compliance with the Bhubaneswar Municipal Corporation area as outlined in various city planning documents. The methodology adopted in this research for locating EV infrastructure includes the research conceptualization, data collection, data analysis, proposal, and recommendation phases. The extensive literature studies identified the tentative tools, techniques, and primary data gathered through surveys. The study used visual survey data, OD survey data, 'traffic volume count survey' data, and mapping of existing infrastructure collected from secondary sources. The data gathered was processed further based on EVs registration details, land use maps, secondary data for calculation of charging demand, land ownership data, land value data, secondary data of existing infrastructure, major routes, and significant nodes, intra - intercity map, travel path data, and traffic volume for categorizing the high, medium, and low-density roads. Secondary data was collected through various sources, including municipal corporations that issued official government reports.

This research makes use of data that is currently available from the Capital Region Urban Transport (CRUT), Regional Transport Office (RTO), Census, and the Bhubaneswar Municipal Corporation (BMC) website. The 'annual growth rate' was calculated with the help of demand calculations for 2025 and 2030.

The authors analyzed to predict the demand for EV infrastructure, EV growth, current infrastructure, required EV charging, and location (gap related to EV travel demand). For EV infrastructure demand projection, parameters including EV traffic behaviour, EV traffic flow, travel pattern, trip length, and bus routes are considered when estimating the demand for EV infrastructure. Additionally, methods that will aid in evaluating the need for infrastructure, such as visual survey, mapping, transportation system assessment, and OD survey, have been used. For EV growth, data on EV registration between 2017 and 2022 helped to analyze the development of EVs in the city. The EV number for 2025 and 2030 for the study area was calculated based on the population and households since the penetration and annual growth rate remain the same. The information on existing infrastructure, including the current charging stations and petrol pumps located within the defined study region, was identified. For determining location (gap related to EVs travel demand), the location of the EVs infrastructure is determined by factors such as the usage of the land, ownership of land, density of populations, travel habits, EVs traffic flow, and bus routes. After demand prediction, the infrastructure demands were mapped. The data set for the existing fuel filling stations was also used to locate the EV charging infrastructure in the current petrol station. Based on each vehicle segment's average battery capacity and driving range, the daily energy requirement for EV Charging was calculated and then multiplied by the projected number of electric vehicles for the different years.

The scenario is developed by considering the city of Bhubaneswar, its rapidly growing population, and a mix of ageing infrastructure. The objectives revolved around integrating e-infrastructure into the existing urban network, transforming Bhubaneswar into a connected, data-driven city that enhances public services and quality of life. Extensive literature studies were conducted to achieve the objectives, parameters relevant to the analysis were identified, and current state analysis and gap identification were performed.

Considering the existing government of India recommendations for achieving the desired usage of EVs by 2030, an infrastructure analysis was conducted to generate the differences between the existing and desired EVs. The desired e-infrastructure was identified based on 2025 and 2030. The areas of intervention and the physical area available within the existing network were identified, and recommendations were made.

2.1 Introduction to the city of Bhubaneswar

The largest capital city of the Indian state of Odisha is Bhubaneswar. With a decadal growth rate of about 2–3%. Bhubaneswar, a planned city in eastern India, has consistently increased its population over the past two decades. It is an educational centre and a desirable business location. The city's population is estimated to be 12 lakhs, and some areas have significant concentrations of PM 2.5, ranging from 50 to 2000 tonnes per year. Bhubaneswar is prepared to keep up with the nation's rapid urbanization. Bhubaneswar has experienced significant urban expansion and land changes due to the city's growing population. It is experiencing pressure to provide the infrastructure and public services required as it transforms itself from being a core of administrative activity to a hub of economic activity. The jurisdiction area of Bhubaneswar is depicted on a map in Figure 1. The purple hatched area is the BMC area of the city.

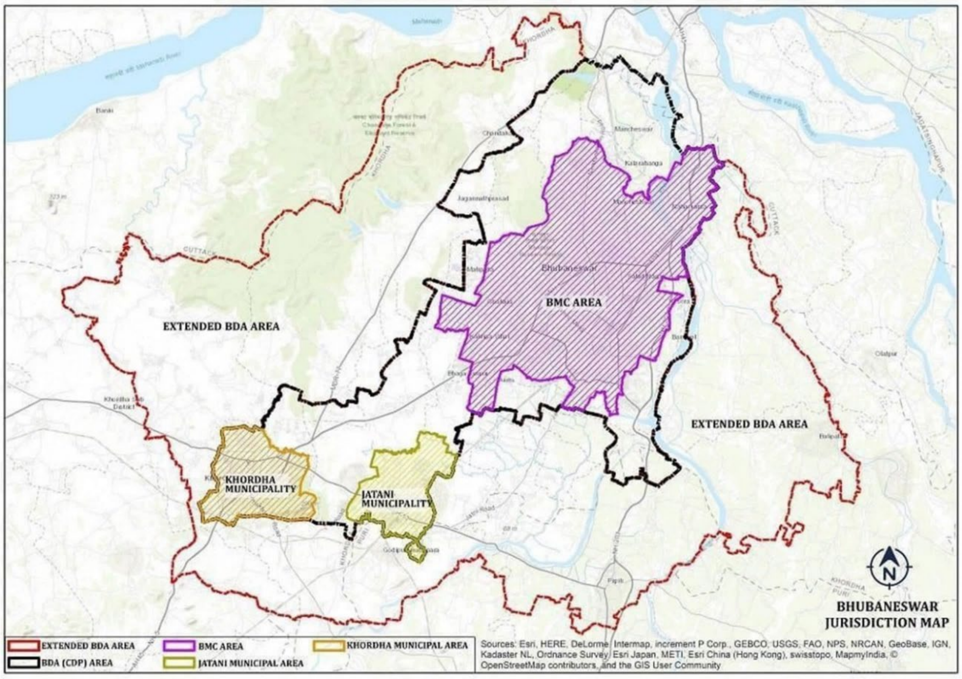

Figure 1. Map showing Bhubaneswar jurisdiction

The city's administrative body is the Bhubaneswar Municipal Corporation (BMC), which covers an area of 186 km^2. North, South-East, and South-West are the three zones that make up the BMC area of the city, and the three zones comprise 67 administrative wards. Figure 2 shows the area under BMC along with the zones and wards. 840,834 people reside in the wards, and there are roughly 103,456 households (https://censusindia.gov.in). The wards have several residential, commercial, educational, public, and semi-public zones. There are presently nine charging stations in the BMC region.

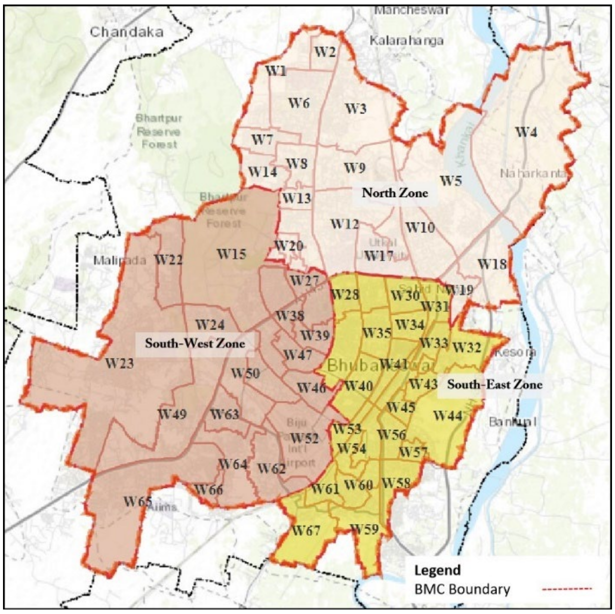

Figure 2. Map showing the area under Bhubaneswar municipal

For this research, the entire BMC area was divided into cells to enable digitization. The BMC area was divided into grids of 1 km^2 (Figure 3). For further processing- ward 40 and its surroundings, which cover a total of 9 km^2, were considered for examination—the study area's estimated population of 162,920, with 20,064 households.

Figure 4 depicts the map of the transport network of Bhubaneswar city. Using technological innovation, service benchmarking, and satisfaction with service, CRUT unveiled its new Mo-bus to completely transform the urban public transport landscape in the city and its environment.

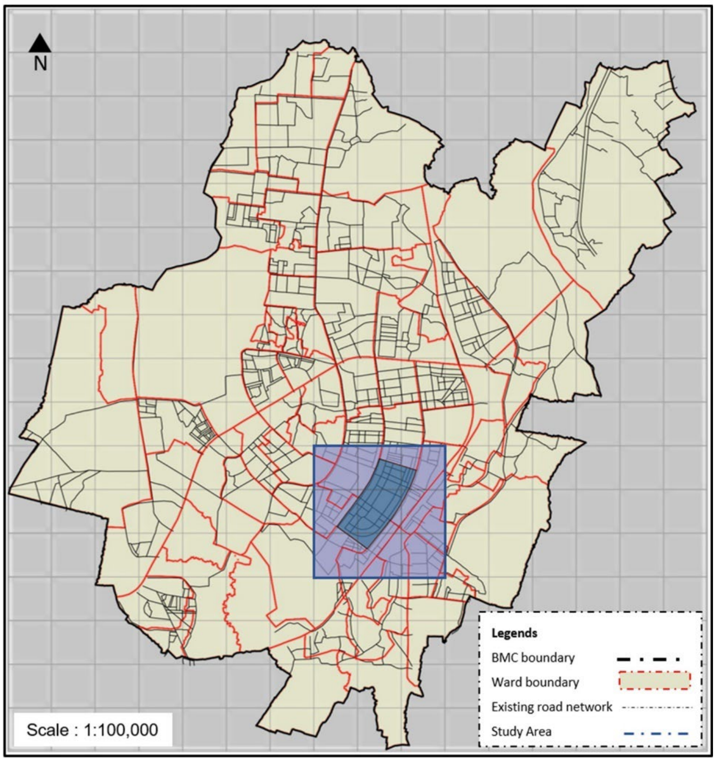

Figure 3. Map showing the study area and the transport network

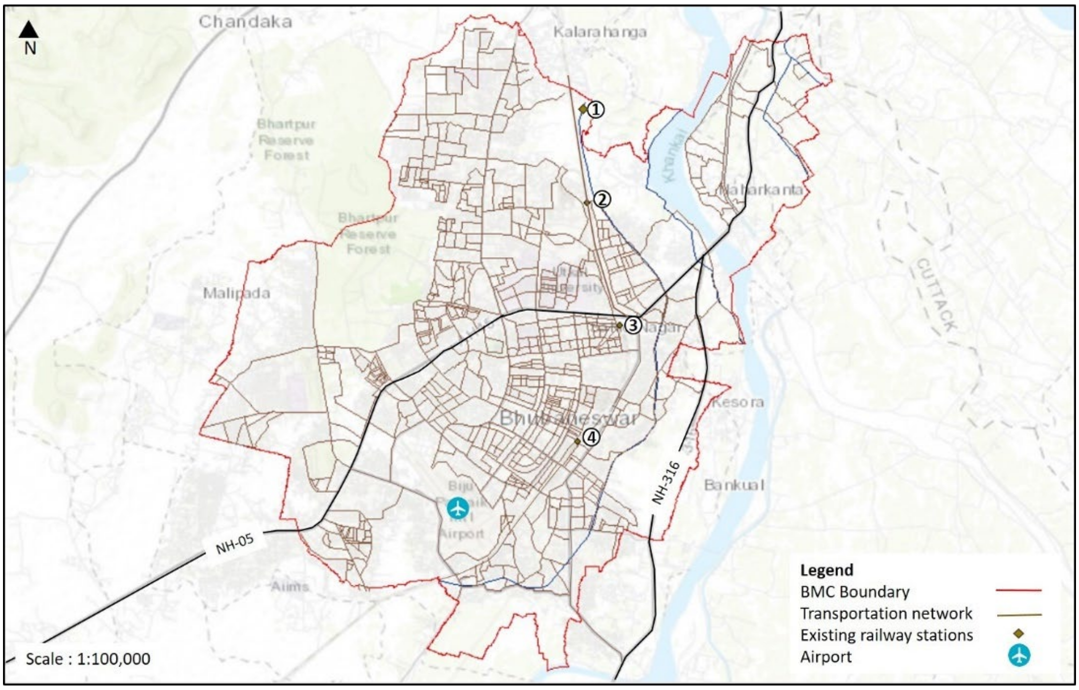

Figure 4. Map showing the transport network of Bhubaneswar

Despite being a planned city, Bhubaneswar has well-designed and marked bus routes that operate throughout the municipality's boundary area of the city. Currently, there are 25 bus routes and 83 stops. In addition, 58 petrol stations and eight charging stations are located along the 915.12 km of roadways in the BMC region. Figure 5 shows a map of the present transport network and the locations of current battery charging and petrol stations.

The region has gradually expanded over time. The area has several primary features: high land value, high activity zones, and mixed land use. A pilot study was done in Ward 40, and its surroundings were earmarked as the "study area," shown in grey in Figure 5. The enormous blow-up of the grey area is shown in Figure 6, delineating the study area and dividing it into grids of 1 km^2. It has a total area of 9 km^2, a projected population of 162,920, and a total number of dwellings of 20,064.

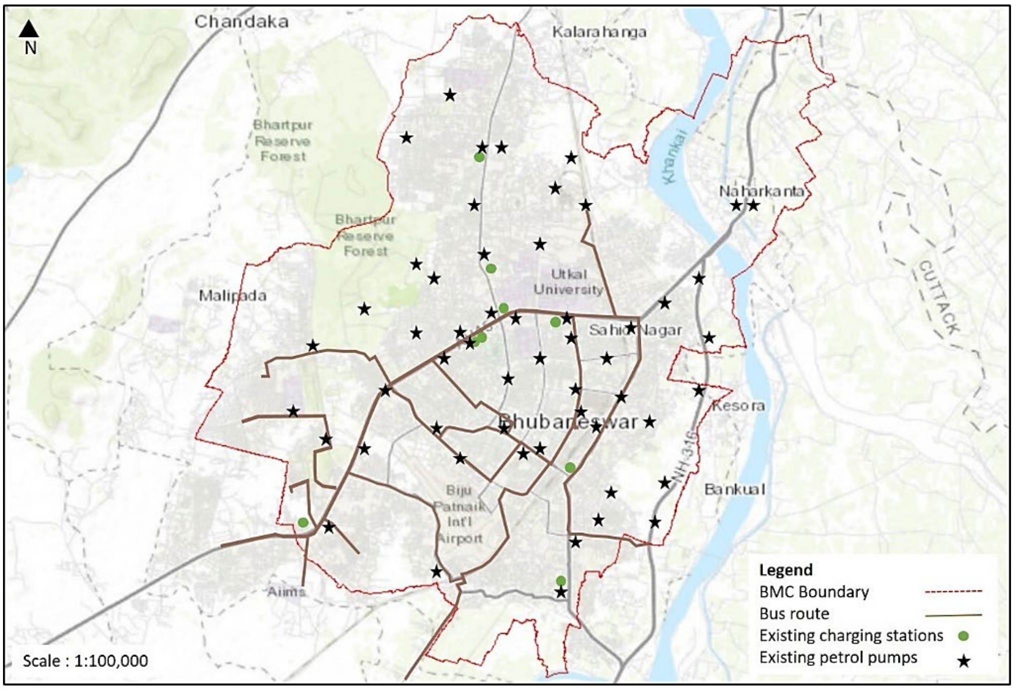

Figure 5. Map showing major bus routes and existing infrastructure

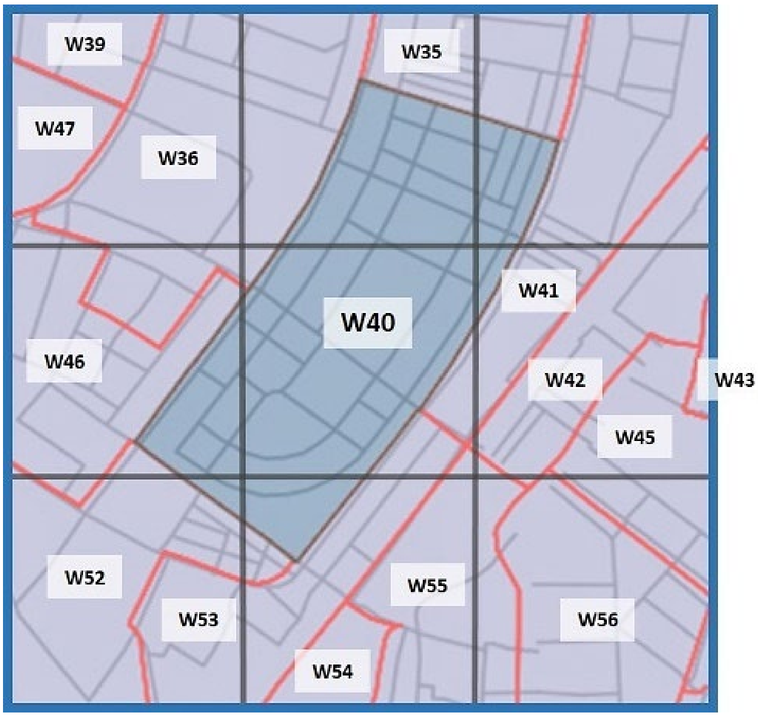

Figure 6. Map of the delineated study area

The status of charging infrastructure in the study area could not be more praiseworthy. Despite the growing use of electric vehicles, a gap exists between the number of chargers available and the number required. One EV charging station is now available along with five fuel stations in the study region (Figure 7), illustrating a gap between the demand for chargers and the number of available chargers.

Figure 7. Map of the existing charging station in the study area and near

3. RESULTS

As an initial step, the BMC area is divided into cells to enable digitization using ArcGIS 10.8. The indicators were used to compile spatialized data, and potential charging demand was ascertained. The input data value was shown on the cells, and then various indicators were given weights based on how they can affect demand. All indicator values were summed for the cells, and a prospective demand category was marked hierarchically. The final formulation of the charging station requirement was based on the demand output obtained for each cell's charging requirement. The location of the infrastructure for public charging is chosen to maximize its ease of availability. All the necessary facilities were considered while allocating the area needed for EV facility provision. In response to the demand for charging multivariate EV requirements, sites facilitated multi-level infrastructure for vehicles with varying charger configurations, and power level demands were identified. It allowed for more efficient and effective integration into the transportation network and lowered the space and electrical load needs at each site. Rather than generating causal claims, a correlation was established with the data to facilitate the development of targeted policy interventions that reduce the suitable implementation of EV charging infrastructure (Khan et al., 2022).

3.1 Geospatial analysis

Digital geospatial analysis using ArcGIS 10.8 identified the demand for public charging infrastructure at a particular cell. A macro-level geospatial analysis determined potential and public charging demands at a unit area level. Site selection for placing public chargers has been made at the local level.

The geographical spread of anticipated EV charging demand was mapped using a spatial analytic method. The relative demand for EVs charging at various sites was predicted using geospatial analysis. The approach was used to disperse accessible charging facilities in multiple locations according to the demand for charging. The analysis helped to determine how charging demand was distributed throughout the study area.

The procedure for conducting geospatial analysis was that the entire BMC region was divided into grid cells of 1 km^2. The criteria that will best depict the potential charging demand were chosen. Varying weights were assigned on different characteristics and their values according to how they might affect future demand when mapping the parameters into the grid's cells. The cells were classified from high to low based on the sum of the values of all the cell properties. The required number of charging points in each cell has a proportional share of the total number of public charging stations; the same was calculated for the planned area based on the charging demand for each cell. In cells with low charging demand, ensuring that accessibility goals were satisfied meant allocating the fewest chargers possible. Ward 40 and its surroundings, which encompass nine grid cells with an area of 9 km^2, were identified for further examination based on parameters determined by population, land use, and activity zones.

3.2 Land use & land ownership analysis

An examination of existing land use and existing land ownership was done using the tools and techniques. The land use map (Figure 8) defined the area as having mixed land use and vacant land. The map showed that most of the vicinity comprises residential land, public and semi-public, and commercial spaces.

Figure 8. Land use map of the study area

The analysis of the ownership pattern (Figure 9) in this area concluded that a significant chunk of land belongs to the state or central government or government undertakings. Secondary data analysis was done using GIS.

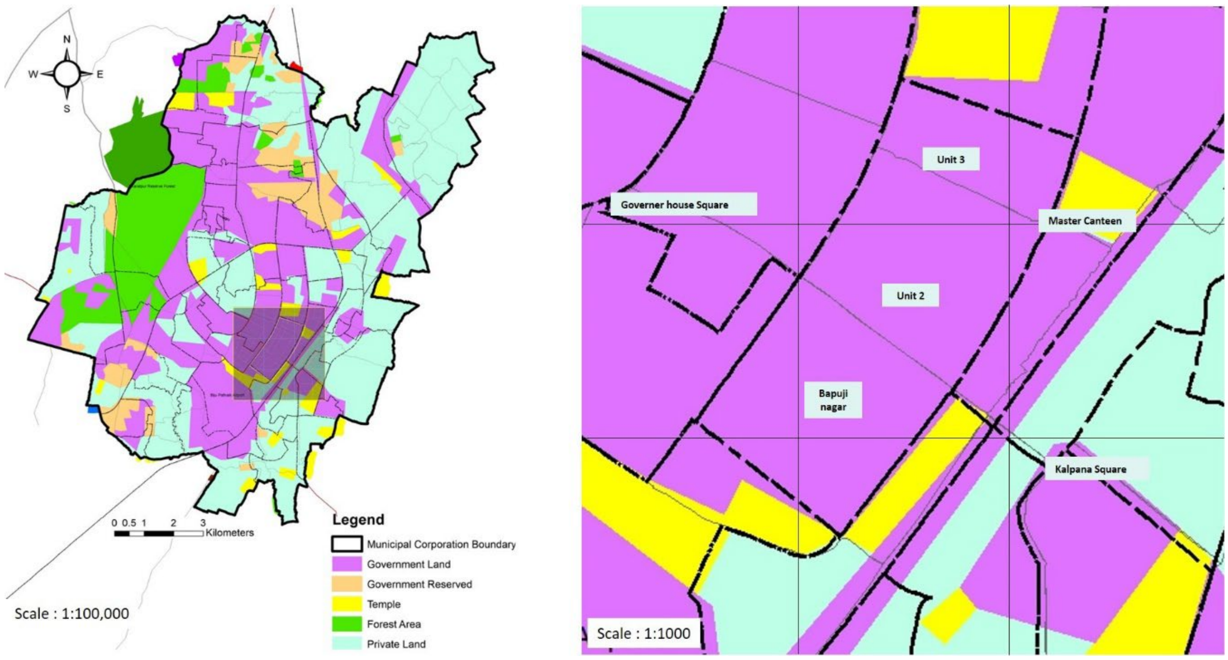

Figure 9. Land use map of the study area

3.3 Visual survey analysis

The analysis was carried out for infrastructure, network, and traffic data using various techniques and tools and considering multiple parameters. The existing road network, major transit road network, structures, parking areas, and significant nodes were restricted in the maps.

Different roads' right of way (ROW) was identified through the existing road network (Figure 10). In major transit road networks, bus lines, flyovers, arterial roads, and local roads were earmarked on the map (Figure 11) of the vital transit roads; this information further assisted in finding public charging areas depending on the density of roads in the research area. It is evident from secondary data that the map displaying the bus route and flyover was classified as a high-density road. The arterial roads on the map are classified as medium-density roads. Low-density road refers to the map that shows local roadways.

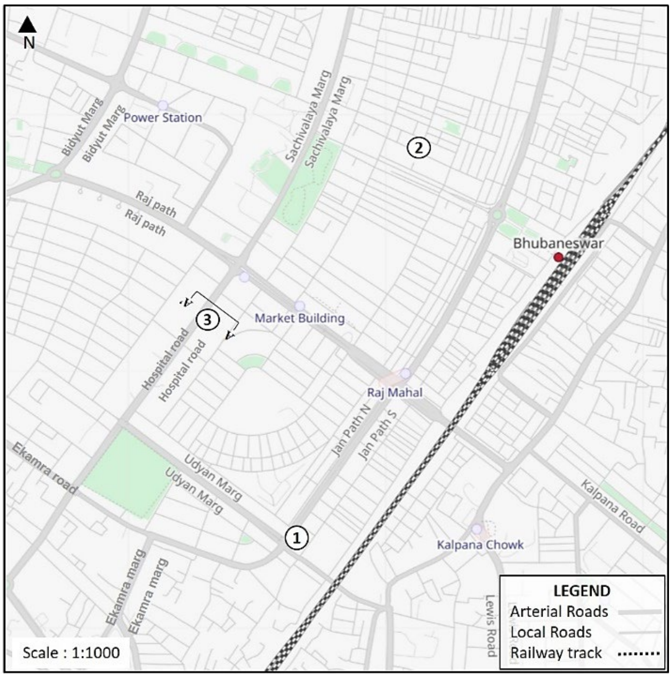

Figure 10. Map showing existing ROW of roads in the study area

Figure 11. Map showing major transit roads in the study area

Around 40 parking lots with approximately 400 parking spaces along Janpath's roads are demarcated in Figure 12, and Figure 13 depicts the significant nodes within the study area.

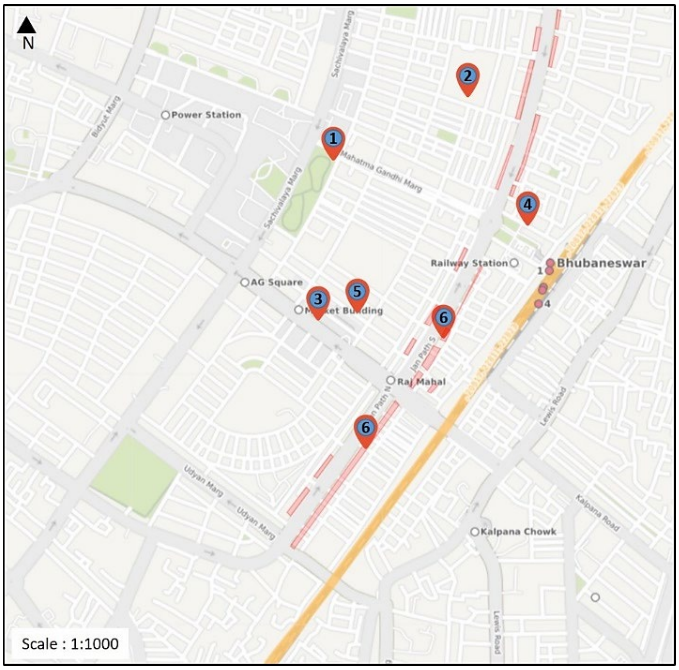

Figure 12. Map showing existing parking in the study area

Figure 13. Map showing significant nodes of the study area

3.3.1 Assessing EVs charging demand

An evaluation of the demand for EV charging was incorporated into planning the charging infrastructure. It was the input data for determining the desired number of public EV chargers. It was used to analyze grid capacity and the need for improvements and to design the locations of public charging infrastructure in the research region.

The following steps were followed for the EV charging demand assessment (Figure 14).

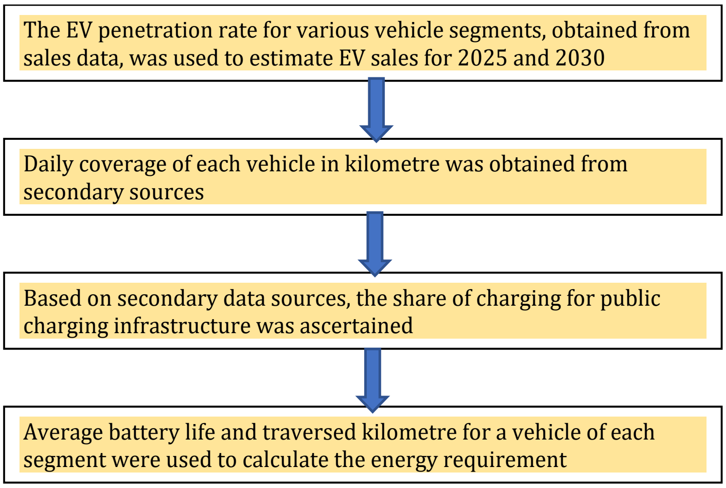

Figure 14. EV charging demand assessment (NITI Aayog, 2021)

With the registration data from Table 1, an EV charging demand assessment was performed (as indicated in Table 3 below), forecasting the demand for public charging for various car segments in the public charging infrastructure. The BMC area in Table 1 refers to the BMC area and Ward 40. Its surroundings were considered for the pilot study and are earmarked as the "study area," shown in grey in Figure 3. Tables 2 and 3 refers to the study area.

3.3.1.1 EVs projections for horizon years by segment

The EV projection has been prepared from the sale data of EVs for the BMC area over the last five years. The projection for the study area is based on EV ownership data obtained through the survey. The base year data of EVs for the area has been taken for 2018 and projected based on annual growth rate and EV penetration rate normalized from NITI Aayog (2021).

3.3.1.2 Charging demand by vehicle segment

Based on data from transportation planning, the estimated demand for the daily kilometres driven by each vehicle segment is illustrated in Tables 4 and 5. The authors determined the daily energy consumption for EV charging based on each car segment's average battery capacity and driving range. The time for charging was given due consideration in calculation by introducing daily charging demand in kWh.

Table 1. Registration of E-vehicle in BMC area

Vehicle segment	2017	2018	2019	2020	2021	2022
E-2wheeler	7	86	96	116	996	4245
E-3wheeler (cargo/passenger)	2	10	12	-	126	150
E-car (private)	-	5	1	9	42	227
E-car (commercial)	-	-	-	6	2	71

Table 2. Projection for BMC area

Vehicle segments	Annual growth	EVs penetration rate - 2025	Total number of EVs - 2025	EVs penetration rate - 2030	Total number of EVs - 2030
E-2W	127%	12%	8695	1.8%	28728
E-3W (passenger/cargo)	215%	10%	1650	1.6%	4290
E-car (personal)	305%	66%	6129	13%	21451
E-car (commercial)	128%	12%	1027	1.8%	2876

Table 3. Projection for the study area

Vehicle segments	Annual growth	EVs penetration rate - 2025	Total number of EVs - 2025	EVs penetration rate - 2030	Total number of EVs - 2030
E-2W	127%	12%	1167	18%	3855
E-3W (passenger/cargo)	215%	10%	80	16%	208
E-car (personal)	305%	66%	736	13%	2876
E-car (commercial)	128%	12%	50	18%	139

Table 4. Projection for BMC area

Vehicle segments	Daily km driven	Battery capacity in kWh	Driving range in km/full charge	Daily charging demand in kWh	Total daily charging demand in kWh - 2025	Total daily charging demand in kWh - 2030
E-2W	45	2.5	100	1.13	62359	174606
E-3W (passenger/cargo)	135	7	120	7.9	13035	33891
E-car (personal)	445	44	313	6.4	97338	1362726
E-car (commercial)	100	21.2	181	12	12324	34512

Table 5. Projection for the study area

Vehicle segments	Daily km driven	Battery capacity in kWh	Driving range in km/full charge	Daily charging demand in kWh	Total daily charging demand in kWh - 2025	Total daily charging demand in kWh - 2030
E-2W	45	2.5	100	1.13	3017	8449
E-3W (passenger/cargo)	135	7	120	7.9	631	1640
E-car (personal)	445	44	313	6.4	4710	65938
E-car (commercial)	100	21.2	181	12	596	1670

3.3.1.3 Type and number of public charging (30% utilization)

The percentage of charging that needs to be done at public charging stations for different car segments is determined by literature studies. For example, private 2Ws and cars could meet most of their charging requirements at home or work and may only need to use public charging stations occasionally. With a single-phase 15A charger, an E-2W takes 8 h for a full charge, an E-3W takes 6 hours for a full charge, and an E-car takes 8 h. The calculation for the number of chargers can be shown as follows:

Number of 2 EW in 2025 (BMC Area) = 8695
Share of public charging @ 13.5% of total vehicle = 644
Each vehicle charging time 8 h

So, for 1 day, the total number of chargers required = 644 x 3 = 1932

The analysis was carried out based on the following considerations, as shown in Tables 6 and 7. The average battery capacity, driving range, and charging share were used to calculate the daily amount of EV charging that different car categories would need at public charging infrastructure. The charger types designated for the different EV segments were determined by classifying the types of chargers presently available in the market based on their voltage level and power rating. An anticipated charge utilization of 30% was used to determine the number of chargers of different types for the public charging infrastructure.

Table 6. Projection for BMC area

Vehicle segments	Share of public charging	Charger types	Average charging time for 100% charge	Number of chargers - 2025	Number of chargers - 2030
E-2W	13.5%	Single phase 15A charger	8 h	1932	6384
E-3W (passenger/cargo)	30%	Single phase 15A charger	6 h	220	572
E-car (personal)	13.5%	Type-2 AC (70%) 50kW DC charger (30%)	8 h	1362	4767
E-car (commercial)	30%	Type-2 AC (60%) 50kW DC charger (40%)	8 h	103	288

Table 7. Projection for the study area

Vehicle segments	Share of public charging	Charger types	Average charging time for 100% charge	Number of chargers - 2025	Number of chargers - 2030
E-2W	13.5%	Single phase 15A charger	8 h	259	856
E-3W (passenger/cargo)	30%	Single phase 15A charger	6 h	11	28
E-car (personal)	13.5%	Type-2 AC (70%) 50kW DC charger (30%)	8 h	163	639
E-car (commercial)	30%	Type-2 AC (60%) 50kW DC charger (40%)	8 h	5	14

4. DISCUSSION

Infrastructure for charging EVs has grown in importance as more EVs enter the roads. The pricing of EV charging is heavily influenced by the density and location efficiency of charging stations within the network of charging stations for electric vehicles. These factors also affect the investment cost and convenience of charging.

The aim of this research revolves around weaving e-infrastructure for green transportation in the current city profile of Bhubaneswar. Notably, green transportation involves using vehicles that do not negatively impact the environment; vis-à-vis are environment-friendly with low emissions (Sarjana, 2023). This green transportation is expected to affect global warming by controlling temperature and contribute to reducing the negativities of climate change (Todorovic & Simic, 2019). According to government directives, all petrol stations should have charging stations in their surroundings to promote EVs. To facilitate this, the government has proposed specific space standards. Provision of a plugin charging station and battery swapping based on the area availability. 5% of parking is to be facilitated with EV charging in all commercial and institutional spaces (as per Ministry of Power, Government of India). Area requirement for different vehicle segments (for plugin and battery swapping) - 1 equivalent car space two-wheeler - 6.58 m^2. 1 equivalent car space for a 3/4-wheeler - 25 m^2.

The demand for electric vehicles will increase, and longer trips will be possible for electric vehicle users if the infrastructure for charging is improved with public fast charging stations. For EV users, rapid charging stations are essential to replicating the usefulness of conventional gas pumps. The developing infrastructure for charging small vehicles, such as 2- and 3-wheelers and interchangeable batteries, are additional solutions.

The Indian government has initiated plans and taken action to encourage the use of EVs rather than gasoline-powered vehicles. According to government directives, all petrol stations should have charging stations in their surroundings to promote EVs. The paper recommends the provision of a plugin charging station and battery swapping on the existing charging stations, which will be based on the area available. Based on the area available, the provision/implementation of the plugin and battery swapping can be provided in the existing petrol pumps if the area is more than 7500 ft^2, and implementation of battery swapping can be provided in the existing petrol pumps if the area is up to 7500 ft^2.

The second recommendation is to provide charging stations in the existing parking spaces. As Bhubaneswar is a planned city, many planned parking spaces are available, which makes the implementation/installation of the charging stations in the existing parking spaces easy. Depending on the power needed, different types can be installed for various car segments.

The infrastructure is allocated according to the demand, quantity, and kind of chargers (plugin or battery-swapping). Infrastructure for public charging should be distributed with the goals of maximizing accessibility, optimizing utilization, and minimizing costs. Digitized geospatial analysis can be used to plan public charging infrastructure locations. The space allocation of the public infrastructure is also based on road density and activity areas. For high-density roads, infrastructure provision can be every two km with six stations. For medium-density roads, infrastructure provision can be every four km with four stations. For low-density roads, infrastructure provision can be every six km with two stations. The activity area proposal is the implementation of five plugin charging stations in the existing parking area.

The policy recommended for this paper follows the government policy that all government vehicles in 2030 should be electrified. Therefore, adequate charging stations must be provided, and subsidies must be better disseminated through tax reductions on chargers and charging stations from 5% to 18% (as per Ministry of Power). To eliminate the gap by 2030, private chargers should be incorporated in independent homes and dedicated parking spots in apartments - which can be self-operated by the EV owners.

5. CONCLUSION

There is a need for references and benchmarks for planning for green transportation in newly developed areas while inter-weaving green transportation into the existing framework of cities. Abiding by these benchmarks makes cities environmentally friendly and makes the transportation network sustainable by using various resources and infrastructure, promoting sustainable transportation. As in the case of Bhubaneswar, the existing planned city provides many opportunities meant to stabilize the environment, making it futuristic and long-lasting. The proposed methodology for the augmentation of sustainable green transportation is purely based on the fact that energy sources will remain electricity derived from sources that do not consume bio-fuels. A sustainable city is characterized by a physically active population supporting a sustainable environment (Cerin et al., 2022). Green transportation studies need to be encouraged to strengthen the depth of the discussion and need to be studied further through knowledge development. In addition, the state government must formulate policies to develop e-infrastructure in Bhubaneswar and other cities to promote environmental sustainability. This will play a pivotal role in further emphasizing the efficient use of green transportation required to ensure the state's sustainable development and integrate it with the country's developmental program targeting renewable energy utilization.

AUTHOR CONTRIBUTIONS

S.P., S.S., and R.K. conceived the presented idea. S.P., S.S., and R.K. developed the theory and performed the computations. S.S. and R.K. verified the analytical methods. S.S. and R.K. encouraged S.P. to collect data and guided her for processing of data and supervised the findings of this work. All authors discussed the results and contributed to the final manuscript.

REFERENCES

Cerin, E., Sallis, J. F., Salvo, D., Hinckson, E., Conway, T. L., Owen, N., van Dyck, D., Lowe, M., Higgs, C., Moudon, A. V., Adams, M. A., Cain, K. L., Christiansen, L. B., Davey, R., Dygrýn, J., Frank, L. D., Reis, R., Sarmiento, O. L., Adlakha, D., Boeing, G., Liu, S., & Giles-Corti, B. (2022). Determining thresholds for spatial urban design and transport features that support walking to create healthy and sustainable cities: Findings from the IPEN Adult study. *The Lancet Global Health*, *10*(6), E895–E906. https://doi.org/10.1016/S2214-109X(22)00068-7

Dai, Z., Liu, H., Rodgers, M. O., & Guensler, R. (2022). Electric vehicle market potential and associated energy and emissions reduction benefits. *Applied Energy*, *322*, Article 119295. https://doi.org/10.1016/j.apenergy.2022.119295

Davis, S. C., & Boundy, R. G. (2021). *Transportation energy data book* (39th ed.). Oak Ridge National Laboratory.

Deb, S. (2020). *Charging infrastructure planning for electric vehicles*. http://gyan.iitg.ernet.in/handle/123456789/1497

Earnest Young. (2022). *Electrifying indian mobility offers opportunities for the world*. Asian Insiders. https://asianinsiders.com/2024/11/19/electrifying-indian-mobility/

IEA. (2022). *World energy outlook 2022*. IEA. https://www.iea.org/reports/world-energy-outlook-2022

IPCC. (2023). *Climate change 2023: Synthesis report. Contribution of working groups I, II and III to the sixth assessment report of the intergovernmental panel on climate change* (H. Lee & J. Romero (Eds.)). https://doi.org/10.59327/IPCC/AR6-9789291691647.001

Khan, H. A. U., Price, S., Avraam, C., & Dvorkin, Y. (2022). Inequitable access to EV charging infrastructure. *The Electricity Journal*, *35*(3), Article 107096. https://doi.org/10.1016/j.tej.2022.107096

Mishra, S., Verma, S., Chowdhury, S., Gaur, A., Mohapatra, S., Dwivedi, G., & Verma, P. (2021). A comprehensive review on developments in electric vehicle charging station infrastructure and present scenario of India. *Sustainability*, *13*(4), Article 2396. https://doi.org/10.3390/su13042396

Mohamed, M., Higgins, C., Ferguson, M., & Kanaroglou, P. (2016). Identifying and characterizing potential electric vehicle adopters in Canada: A two-stage modeling approach. *Transport Policy*, *52*, 100–112. https://doi.org/10.1016/j.tranpol.2016.07.006

NITI Aayog. (2021). *Handbook of electric vehicle charging infrastructure implementation*. WRI India Ross Center.

NRDC India. (2022). *Fueling ZEV transition - Global review of supply-side regulations and India's opportunity*. NRDC.

Peng, L., Liu, F., Zhou, M., Li, M., Zhang, Q., & Mauzerall, D. L. (2021). Alternaive-energy-vehicle deployment delivers climate, air uality, and health co-benefits when coupled with decarbonizing power generation in China. *One Earth*, *4*(8), 1127–1140. https://doi.org/10.1016/j.oneear.2021.07.007

Sarjana, S. (2023). Green transportation: Development opportunities in support of sustainable transportation. *E3S Web of Conferences*, *429*, Article 03003. https://doi.org/10.1051/e3sconf/202342903003

Shi, L., Hao, Y., Shengnan, L., Cipcigan, L., & Liang, J. (2021). A comprehensive charging network planning scheme for promoting EV charging infrastructure considering the chicken-eggs dilemma. *Research in Transportation Economics*, *88*, Article 100837. https://doi.org/10.1016/j.retrec.2020.100837

SIAM. (2017). *Annual report 2017–18*. Society of Indian Automobile Manufacturers. https://www.siam.in/uploads/ar/20-20thAnnual%20Report2017-2018.PDF

Todorovic, M., & Simic, M. (2019). Feasibility study on green transportation. *Energy Procedia*, *160*, 534–541. https://doi.org/10.1016/j.egypro.2019.02.203

Zhao, X., Hu, H., Yuan, H., & Chu, X. (2023). How does adoption of electric vehicles reduce carbon emissions? Evidence from China. *Heliyon*, *9*(9), Article e20296. https://doi.org/10.1016/j.heliyon.2023.e20296