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Multi-Criteria Spatial Analysis and Accessibility Assessment for Optimizing Public Electric Vehicle Charging Station (EVCS) Locations in Bandung City

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Abstract

Background: The transition toward low-carbon transportation and the growing commitment to achieving Net Zero Emissions (NZE) have increased the importance of electric vehicle adoption in Indonesia. In Bandung City, however, the spatial distribution of Public Electric Vehicle Charging Stations (EVCS) remains concentrated in central urban areas, creating disparities in service coverage across different districts.
Objective: This study aims to identify priority areas for EVCS development in Bandung City by integrating spatial and multi-criteria analyses.
Methods: A quantitative GIS-based approach was employed by combining spatial distribution analysis, buffer analysis (3 km and 5 km), accessibility assessment, service gap analysis, and the Analytical Hierarchy Process (AHP). AHP weights were obtained from pairwise comparisons by eight experts from PLN, the Bandung City Transportation Agency, urban planning practitioners, and academics, aggregated using the geometric mean.
Results: The findings reveal that EVCS facilities are concentrated in the city center, with 32 of 64 units (50.00%) located in central districts and 11 units (17.19%) along the Soekarno-Hatta corridor. AHP weighting produced population density 0.40, accessibility 0.30, distance from existing EVCS 0.20, and proximity to activity centers 0.10, with a Consistency Ratio of 0.08. Weighted overlay yielded the highest suitability scores for Gedebage (4.72) and Cibiru (4.58), followed by Rancasari (4.41), Arcamanik (4.27), and Cinambo (4.15).
Conclusion: The GIS-AHP framework translates spatial inequity into a ranked development priority list, giving PLN, local government, and infrastructure investors an evidence-based instrument for allocating charging capacity equitably and for embedding service-equity criteria into sustainable transportation and energy transition policy.

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INTRODUCTION

Growing concerns regarding energy security, environmental sustainability, and carbon emission reduction have accelerated the transition toward cleaner transportation systems worldwide. The transportation sector remains one of the largest contributors to greenhouse gas emissions, creating significant challenges for achieving sustainable development goals and Net Zero Emission (NZE) targets. Consequently, many countries have intensified efforts to promote low-emission mobility solutions and reduce dependence on fossil-fuel-based transportation systems (Litman, 2022; International Energy Agency, 2023).

Among the available alternatives, electric vehicles (EVs) have emerged as a promising solution due to their higher energy efficiency and lower environmental impact compared with conventional internal combustion engine vehicles. Recognizing these benefits, the Government of Indonesia has introduced various policies and regulatory frameworks to accelerate EV adoption and support the development of a sustainable transportation ecosystem. One of the most important supporting infrastructures is the Public Electric Vehicle Charging Station (EVCS), which plays a crucial role in ensuring the operational reliability and convenience of electric vehicle users (Wahyudi et al., 2024).

At the national level, the growth of electric vehicle ownership in Indonesia has been substantial. Data recorded through the Type Test Registration Certificate (SRUT) system of the Directorate General of Land Transportation show that the population of battery-based electric motor vehicles increased from 3,894 units in 2020 to 41,743 units in 2022, 207,478 units in 2024, and 342,118 units at the end of December 2025, comprising 229,820 electric motorcycles, 110,524 passenger cars, 778 three-wheeled vehicles, 723 buses, and 273 goods vehicles (Indonesia, 2026). Although this represents an increase of more than eighty-fold within five years, electric vehicles still account for less than one percent of the national fleet of approximately 172.93 million vehicles, and the figure remains far below the government target of two million electric cars and thirteen million electric motorcycles by 2030. The persistence of this gap indicates that the acceleration of adoption depends less on vehicle supply than on the readiness, capacity, and spatial distribution of the supporting charging network.

Studies conducted in other metropolitan areas confirm that charging infrastructure tends to follow commercial concentration rather than population distribution. Research in Guangzhou applying the Gaussian two-step floating catchment area method found that charging accessibility was highest in the western districts and lowest at the urban fringe, with automotive service facilities, distance to the regional centre, and distance to subway stations acting as the dominant explanatory variables (Sheng et al., 2025). A bibliometric review of 1,336 publications covering the period 2016 to 2025 further reports that AHP and TOPSIS remain the two most frequently applied multi-criteria methods in charging station siting, while the treatment of spatial equity as an explicit planning constraint is still uncommon (Li et al., 2025b). Systematic reviews of GIS-based siting likewise note that most models optimise coverage or cost, whereas the distributional consequences of the resulting network receive limited attention (Banegas & Mamkhezri, 2023). Taken together, these findings suggest that a siting framework applied to an Indonesian metropolitan area needs to treat service equity as an analytical objective rather than as a residual outcome of demand-driven investment.

Despite the increasing growth of electric vehicle adoption, the provision of charging infrastructure remains a major challenge in many urban areas. The limited availability and uneven distribution of EVCS facilities can reduce user confidence and contribute to range anxiety, a condition in which drivers are concerned about their ability to access charging facilities before battery depletion (Wang et al., 2026; Zhang & Tian, 2021). This issue is particularly relevant in rapidly growing metropolitan areas where travel demand and mobility patterns vary significantly across regions.

Bandung City is one of Indonesia’s major urban centers with substantial potential for electric vehicle development due to its high population density, economic activities, and transportation demand. However, existing EVCS facilities are predominantly concentrated in the city center and along major commercial corridors, while several peripheral districts remain underserved. Such spatial imbalance may limit accessibility to charging services and reduce the effectiveness of EV infrastructure development in supporting future mobility demands (Spyropoulos et al., 2025).

Previous studies have examined EVCS planning from various perspectives, including spatial distribution assessment, demand forecasting, and site selection analysis. Nevertheless, most studies have addressed these aspects separately, with limited integration of spatial distribution patterns, accessibility evaluation, and service gap assessment within a unified decision-support framework (Wang et al., 2025). To address this research gap, the present study integrates Geographic Information Systems (GIS), spatial analysis, buffer analysis, accessibility assessment, gap analysis, and the Analytical Hierarchy Process (AHP) to identify priority areas for EVCS development in Bandung City.

The novelty of this study lies in three aspects. First, it combines spatial distribution analysis, buffer-based service coverage evaluation, accessibility measurement, and service gap analysis within a single sequential workflow, so that the criteria entering the Analytical Hierarchy Process are derived from empirically observed service deficits rather than from a predetermined list of candidate sites. Second, it positions service equity, expressed as the gap between potential demand and available charging capacity at the district level, as an explicit decision criterion, which addresses a limitation repeatedly identified in earlier GIS-MCDM studies. Third, it provides the first district-level suitability ranking for Bandung City based on a complete inventory of the sixty-four operating public charging stations, thereby producing a transferable and auditable procedure for other Indonesian cities with comparable spatial and demographic characteristics (Rashmitha et al., 2024).

The proposed approach is expected to provide a more comprehensive basis for infrastructure planning by considering both spatial characteristics and service requirements. The findings of this study may contribute to the development of a more equitable and efficient EV charging network while supporting sustainable urban transportation policies and Indonesia's long-term energy transition agenda.

Theoretically, this study contributes to the literature on facility location and spatial equity by demonstrating how location-allocation reasoning can be operationalised through a staged GIS-MCDM procedure in a data-constrained urban setting. Practically, the results are directed at three groups of stakeholders. For the Bandung City Government, the priority ranking provides a spatial basis for integrating charging infrastructure into the regional spatial plan and into local low-emission transport programmes. For PLN as the principal operator, the identification of critical gap districts offers an objective criterion for allocating investment beyond commercially attractive corridors. For private developers and charge point operators, the suitability scores indicate districts in which future demand is likely to grow while competition is presently low, which reduces the risk of overinvestment in already saturated central areas.

METHOD

This study adopted a quantitative approach based on Multi-Criteria Spatial Analysis integrated with Geographic Information Systems (GIS) to identify priority locations for Public Electric Vehicle Charging Station (EVCS) development in Bandung City. The GIS-based approach was selected because it enables the integration of spatial and non-spatial variables within a single analytical framework, thereby supporting objective and data-driven decision-making in infrastructure planning (Li et al., 2025b; Loew, 2017). The analysis incorporated spatial distribution analysis, buffer analysis, accessibility analysis, gap analysis, the Analytical Hierarchy Process (AHP), and Weighted Overlay Analysis to evaluate the suitability of potential EVCS locations. Through the integration of these methods, the study generated a priority map that identifies areas requiring additional charging infrastructure to improve service coverage, accessibility, and the equitable distribution of EVCS facilities across Bandung City (Abdullah et al., 2026; Burrough & Mcdonnell, 1998).

This study was carried out in Bandung City, West Java Province, Indonesia, an urban area characterized by intensive transportation activities, rapid urban development, and growing potential for electric vehicle adoption. The selection of Bandung City as the study area was based on its strategic role as a metropolitan center with increasing demand for sustainable transportation infrastructure. Both primary and secondary data were utilized to support the analysis. Primary data were collected through field observations to identify existing Electric Vehicle Charging Station (EVCS) locations and to validate accessibility conditions within the study area. Secondary data comprised information on EVCS locations, transportation networks, population distribution, urban activity centers, and administrative boundaries. These datasets were obtained from various official and publicly available sources, including PLN, Statistics Indonesia (BPS), the Geospatial Information Agency (BIG), OpenStreetMap, and other relevant databases. The integration of these datasets provided a comprehensive basis for conducting spatial analysis and evaluating priority locations for future EVCS development (Badan Pusat Statistik, 2025).

Spatial data validation was carried out in three stages. First, EVCS point data obtained from PLN and from publicly accessible charging directories were cross-checked against OpenStreetMap and high-resolution satellite imagery in order to remove duplicated entries and to correct coordinates deviating from the actual building footprint. Second, ground checking was conducted at a sample of the recorded locations, distributed proportionally across the five spatial clusters of the city, to confirm the existence, operational status, connector type, and rated capacity of each station. Third, coordinates verified in the field were used as control points to adjust the remaining desk-based records, while administrative boundary and population layers obtained from the Geospatial Information Agency and Statistics Indonesia were reprojected to WGS 1984 UTM Zone 48S and checked topologically before the overlay procedure. Records that could not be verified were excluded from the analysis, so that only validated points entered the buffer, accessibility, and gap analyses.

Table 1
Research Variables

Variable	Indicator	Unit	Source
Population Density	Population Size	Persons	BPS
Accessibility	Distance to Major Roads	km	GIS
Urban Activity	Number of Activity Centers	Unit	Observation
Existing EV Charging Stations (EVCS)	Number of EV Charging Stations	Unit	PLN
Service Coverage	Buffer Radius	km	GIS

Source: research data

Analysis Method

Spatial Distribution Analysis of EVCS

A GIS-based spatial distribution analysis was performed to examine the geographic pattern of existing Public Electric Vehicle Charging Stations (EVCS) in Bandung City. The analysis focused on identifying the spatial concentration of charging facilities and evaluating their distribution relative to urban characteristics, including population distribution, transportation networks, and major activity centers. By visualizing and assessing the spatial arrangement of EVCS locations, this analysis provided essential information for evaluating service coverage and identifying areas that may require additional charging infrastructure. The findings were subsequently used to support the assessment of service equity and to establish priority zones for future EVCS development (Li et al., 2025b; Loew, 2017; Longley et al., 2004b).

Buffer Analysis of Service Coverage

Buffer analysis was applied to delineate the service coverage of every validated charging station. Two service radii were used, namely 3 km as the optimum coverage and 5 km as the maximum coverage. The selection of these radii follows the distance thresholds commonly adopted in urban charging accessibility research. A radius of 3 km approximates the distance that urban electric vehicle users are willing to travel for routine charging, whereas 5 km corresponds to the comfortable intra-urban driving distance reported in accessibility assessments of charging infrastructure, which is equivalent to approximately ten minutes of travel time at the average urban network speed (Sheng et al., 2025). Comparable service radii ranging from 1 km to 5 km have also been applied in equity assessments of public charging networks in dense metropolitan areas (Banegas & Mamkhezri, 2023). The two radii were therefore treated as a lower and an upper bound of realistic service coverage rather than as fixed engineering standards, and the difference between the two buffers was used to identify districts whose access to charging services is marginal.

Accessibility Analysis

An accessibility analysis was conducted to measure the ease of access for electric vehicle users to service stations (EVCS). Parameters used included distance to arterial roads, distance to urban activity centers, and travel time to the EVCS location. Accessibility calculations were based on the Hansen model.

$$A_i = \Sigma(W_j / d_{ij}^\beta)$$

where:
1. A_i = accessibility level of location i
2. W_j = activity weight at location j
3. d_{ij} = distance between locations i and j
4. β = travel obstacle parameter

Accessibility values are then normalized to a 0–1 scale for ease of interpretation.

Gap Analysis

Gap analysis is used to identify gaps between EVCS service levels and regional needs. The analysis is conducted using an overlay technique between buffer maps, population density, and urban activity centers. The analysis results are classified into three main categories:
1. High Service – High Demand
2. Low Service – High Demand (Critical Gap)
3. Low Service – Low Demand

Areas that fall into the Critical Gap category are the main priority in EVCS development.

Location Optimization Using the Analytical Hierarchy Process (AHP)

Prioritization of EVCS locations was conducted using the Analytical Hierarchy Process (AHP) method. The criteria used included:
1. Population density
2. Accessibility
3. Distance to existing EVCS
4. Proximity to activity centers

The weighting of each criterion was obtained through a pairwise comparison matrix. The consistency of the assessment was tested using the Consistency Ratio (CR), where the matrix was considered consistent if $CR < 0.10$.

The pairwise comparison matrix was constructed from the judgements of eight respondents selected purposively on the basis of professional relevance, comprising two engineers from PLN Unit Induk Distribusi Jawa Barat, two officials from the Bandung City Transportation Agency, two urban planning practitioners, and two academics in the fields of transportation and spatial planning. Each respondent completed a questionnaire using the Saaty nine-point scale covering all six pairwise combinations of the four criteria. Individual matrices were aggregated using the geometric mean method, which preserves the reciprocal property of the aggregated matrix and is the aggregation procedure recommended for group AHP. Consistency was tested for each individual matrix and for the aggregated matrix, and only matrices with a Consistency Ratio below 0.10 were retained. The aggregated matrix produced a Consistency Ratio of 0.08, so the resulting weights were considered consistent and suitable for use in the weighted overlay stage (Kaya et al., 2022).

GIS Integration and Weighted Overlay Analysis

The AHP weighting results were integrated into a GIS using Weighted Overlay Analysis to generate a suitability map of EVCS locations. The model used is:

$$S = \Sigma(W_i \times X_i)$$

where:

S = location suitability score

W_i = weight of the i-th criterion

X_i = value of the i-th parameter

The higher the suitability score, the higher the priority level of the area for EVCS development. The final output includes a location priority map, regional ranking, and recommendations for EVCS development in Bandung City.

RESULTS AND DISCUSSION

Spatial Distribution Analysis of EVCS in Bandung City (GIS Analysis)

Existing Location Mapping

Mapping was conducted for all existing charging stations (EVCS) locations in Bandung City using a Geographic Information System (GIS). Based on the data inventory results, there are 64 EVCS points spread across various sub-districts in Bandung City. These EVCSs consist of various charging types, namely standard charging, medium charging, fast charging, and ultra-fast charging with capacities ranging from 7 kW to 200 kW. Most of the EVCSs are located at PLN offices, shopping centers, electric vehicle dealerships, hotels, commercial areas, and main road corridors. This mapping aims to obtain a spatial overview of the location of currently available electric vehicle charging facilities as a basis for analyzing the distribution and service of electric vehicle infrastructure.

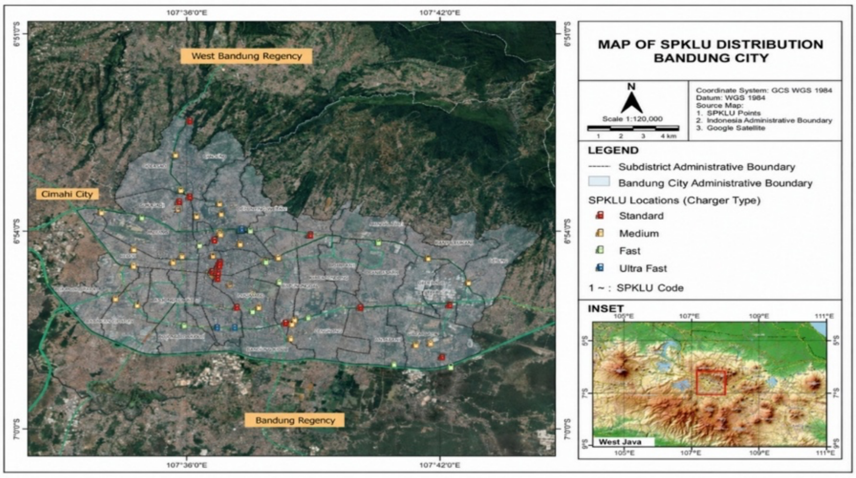

Figure 1. *Spatial Distribution Map of Public Electric Vehicle Charging Stations (EVCS) in Bandung City*

Spatial Distribution Analysis of EVCS

Spatial analysis results show that the distribution of service stations (EVCS) in Bandung City remains uneven. Most are concentrated in the city center, such as the districts of Sumur Bandung, Bandung Wetan, Coblong, Lengkong, and Andir. These areas are centers of government, trade, services, education, and tourism, with high levels of mobility.

Of the 64 identified EVCSs, exactly 50.00%, or 32 of the 64 units, are located in the city center and main road corridors. This indicates that current EVCS development is still oriented towards areas with high levels of demand and economic activity (demand-driven infrastructure development). Furthermore, EVCSs are found in many corridors including Soekarno–Hatta Road, Ahmad Yani Road, Asia Afrika Road, Ir. H. Juanda Road (Dago), and Surapati Road. Which offer high accessibility to the urban transportation network. Every percentage reported in this section is obtained by dividing the number of EVCS recorded in a given spatial cluster or road corridor by the total inventory of 64 validated units, as presented in Table 2 and Table 7.

Table 2

Distribution of EVCS Based on Bandung City Region

No	District	City	Province	Population	Area (m^2)	Area (km^2)	Number of EV Charging Stations (EVCS)	Population Density (people/km^2)
1	Andir	Bandung	West Java	99897	4.237.840	4,238	3	23.572
2	Antapani	Bandung	West Java	85335	4.219.330	4,219	0	20.226
3	Arcamanik	Bandung	West Java	85868	7.335.090	7,335	1	11.707
4	Astana Anyar	Bandung	West Java	71503	2.640.340	2,64	0	27.084
5	Babakan Ciparay	Bandung	West Java	146483	7.031.540	7,032	1	20.831
6	Bandung Kidul	Bandung	West Java	62980	4.988.720	4,989	0	12.624
7	Bandung Kulon	Bandung	West Java	142755	6.710.860	6,711	1	21.272
8	Bandung Wetan	Bandung	West Java	27600	3.396.640	3,397	7	8.125
9	Batununggal	Bandung	West Java	118711	4.756.550	4,757	3	24.955
10	Bojongloa Kaler	Bandung	West Java	123500	3.063.440	3,063	0	40.320

No	District	City	Province	Population	Area (m^2)	Area (km^2)	Number of EV Charging Stations (EVCS)	Population Density (people/km^2)
11	Bojongloa Kidul	Bandung	West Java	90755	4.937.610	4,938	1	18.379
12	Buahbatu	Bandung	West Java	107518	7.359.120	7,359	3	14.610
13	Cibeunying Kaler	Bandung	West Java	69861	4.576.920	4,577	2	15.263
14	Cibeunying Kidul	Bandung	West Java	111801	4.093.450	4,093	2	27.315
15	Cibiru	Bandung	West Java	76538	6.950.760	6,951	1	11.011
16	Cicendo	Bandung	West Java	95813	7.537.910	7,538	3	12.711
17	Cidadap	Bandung	West Java	54867	7.672.650	7,673	3	7.151
18	Cinambo	Bandung	West Java	26903	4.218.730	4,219	0	6.377
19	Coblong	Bandung	West Java	113267	7.195.330	7,195	4	15.742
20	Gedebage	Bandung	West Java	47030	9.781.040	9,781	4	4.808
21	Kiaracondong	Bandung	West Java	131860	5.691.610	5,692	3	23.166
22	Lengkong	Bandung	West Java	68624	5.802.000	5,802	6	11.828
23	Mandalajati	Bandung	West Java	79339	4.720.190	4,72	0	16.809
24	Panyileukan	Bandung	West Java	42142	5.072.050	5,072	0	8.309
25	Rancasari	Bandung	West Java	92203	6.849.330	6,849	1	13.462
26	Regol	Bandung	West Java	81995	4.863.420	4,863	4	16.861
27	Sukajadi	Bandung	West Java	103465	5.136.570	5,137	2	20.141
28	Sukasari	Bandung	West Java	76967	6.337.260	6,337	1	12.146
29	Sumur Bandung	Bandung	West Java	35086	3.439.680	3,44	7	10.199
30	Ujungberung	Bandung	West Java	98886	5.978.340	5,978	1	16.542
	TOTAL			**2569102**	166.594.323	**166.595**	64	15.421

Population density is calculated as the total population of a district divided by its administrative area in square kilometres, using the district population and area figures reported in the same table. The area recorded in square metres has been corrected so that it is numerically consistent with the area expressed in square kilometres.

Table 3

Distribution of EVCS Based on Spatial Cluster of Bandung City

Region	Dominant Sub-district	Number of EVCS	Percentage (%)	Distribution characteristics	Category
City Center	Sumur Bandung, Bandung Wetan, Coblong, Lengkong	32	50,00	Concentrated on activity centers and offices	Clustered
North	Sukasari, Cibeunying Kaler, Cidadap	8	12,50	Follows main road corridors and educational areas	Medium
West	Andir, Cicendo, Bandung Kulon, Bojongloa Kaler	10	15,63	Close to commercial and transportation areas	Medium
South	Regol, Batununggal, Buahbatu	5	7.81	Near commercial and transportation areas	Low
East	Gedebage, Cibiru, Arcamanik, Cinambo, Kiaracondong	9	14,06	The distance between facilities is relatively far	Low
		64	100,00		

Based on Table 3, the distribution of EVCS in Bandung City is still dominated by the city center, with 32 locations, or 50.00% of the total of 64 EVCS. The remaining facilities are distributed across the western cluster (10 locations, 15.63%), the eastern cluster (9 locations, 14.06%), the northern cluster (8 locations, 12.50%), and the southern cluster (5 locations, 7.81%), particularly along the Soekarno-Hatta, Buahbatu, Gedebage, and Kiaracondong corridors. Each percentage is obtained by dividing the number of EVCS in a cluster by the total of 64 units.

Table 4

Distribution of EVCS Based on Type of Activity Center

Types of Activity Centers	Location Examples	Number of EVCS	Percentage (%)	Characteristics
PLN office / energy utilities	PLN IP3, ULP, UID, CSE, DAYA+	13	20,31	The main facilities of the charging service provider
Hotels and apartments	De Braga, Preanger, Crowne Plaza, Gaia, Gateway Pasteur	15	23,44	Supporting EV users in tourism and accommodation activities
Electric vehicle / automotive dealer	Hyundai, Toyota, BYD, Wuling	14	21,88	Generally semi-public or brand specific
Shopping center / mall	PVJ, Trans Studio Mall, 23 Paskal, Summarecon Mall	5	7,81	Located in a commercial area with a relatively long parking duration
Government offices / public facilities	Balai Kota Bandung, Polda Jabar, BTN Kanwil Jabar	3	4,69	Supporting public services and business travel

Rest area / restaurant / tourist area	Rest Area KM 147A, Geowisata Inn, Malaga Resto	4	6,25	Serving inter-regional travel and tourism activities
Other commercial areas	Wisma HSBC, Tenth Avenue, Paberik Badjoe, Lasumi Alus	10	15,63	Spread across trade and service activity centers
Total	-	**64**	**100,00**	-

Table 4 shows that the distribution of EVCS in Bandung City is mostly found in hotels and apartments (15 locations, or 23.44%), followed by electric vehicle/automotive dealerships (14 locations, or 21.88%), and PLN/energy utility offices (13 locations, or 20.31%). This condition indicates that the development of EVCS is still heavily influenced by centers of economic activity, accommodation, and automotive services. This pattern supports the needs of electric vehicle users in locations with relatively long parking durations, such as hotels, shopping centers, and commercial areas, but also indicates that EVCS facilities are not yet fully distributed based on residential needs and population density.

EVCS Service Coverage Analysis (Buffer Analysis)

A service coverage analysis (Buffer Analysis) was conducted to evaluate the service coverage level of Public Electric Vehicle Charging Stations (EVCS) in the Bandung City area. This analysis aims to identify areas that have been served and areas that still experience limited access to electric vehicle charging facilities. In this study, buffer radii of 3 km and 5 km were used, which represent the optimal service coverage and maximum service coverage of EVCS in urban areas. According to Burrough and McDonnell (1998), buffer analysis is a spatial analysis technique used to determine the zone of influence of a facility based on a certain distance from the facility's location (Abdullah et al., 2026).

Based on a GIS analysis of 64 charging stations (EVCS) in Bandung, the majority of the city center is within a 3-km service radius. The districts of Sumur Bandung, Bandung Wetan, Coblong, Lengkong, Andir, and parts of Cibeunying Kidul have relatively high service levels due to their proximity to existing charging stations. This indicates that residents in the city center have greater access to electric vehicle charging facilities than other areas.

The analysis also shows the phenomenon of overlapping service areas in the city center. This overlap occurs due to the high concentration of service stations (EVCS) located in centers of economic activity, commerce, hotels, shopping centers, and office areas. While this situation can increase facility utilization, overly concentrated distribution has the potential to create spatial inefficiencies, as some areas receive excess service while others experience limited access.

Within a 5-km service radius, service coverage has increased significantly, reaching most of Bandung City's administrative areas. However, the overlay results show that several areas in the eastern and southern parts of the city still have relatively low service levels. The districts of Gedebage, Cibiru, Arcamanik, Cinambo, and parts of Rancasari are still relatively far from existing charging stations, thus suboptimal public access to electric vehicle charging facilities.

When linked to regional demographic characteristics, it was found that several sub-districts with significant populations have not received comparable service coverage. Rancasari sub-district has a population of approximately 92,203, Cibiru approximately 76,538, and Gedebage approximately 47,030, yet still have limited access to charging stations compared to the city center. This situation indicates a service gap between areas with high potential demand and limited charging infrastructure availability.

The results of this study align with those of Li et al. (2025b), who stated that evaluating service coverage is a crucial step in EVCS location planning because it can identify underserved areas. Furthermore, Spyropoulos et al. (2025) explained that overly concentrated distribution of charging facilities in city centers can improve operational efficiency, but has the potential to create unequal access to services for people in peripheral areas.

Overall, the Buffer Analysis results show that although most core areas of Bandung City have a good level of service, there are still several outlying areas that experience limited access to EVCS. This condition indicates that the distribution of electric vehicle infrastructure in Bandung City does not fully meet the principle of equal service distribution. Therefore, areas outside the optimal service coverage, particularly Gedebage, Cibiru, Arcamanik, and Rancasari, need to be prioritized for future EVCS development. These findings will then serve as the basis for implementing Accessibility Analysis and Gap Analysis to determine priority areas for EVCS development more objectively and based on regional needs.

Table 5
Service Coverage of Districts Based on 3 km and 5 km Buffer Analysis

Spatial Cluster	Representative Districts	Coverage within the 3 km Buffer	Coverage within the 5 km Buffer	Coverage Status
City Center	Sumur Bandung, Bandung Wetan, Coblong, Lengkong, Andir	Fully covered with overlapping buffers	Fully covered	Served to over-served
North	Sukasari, Cibeunying Kaler, Cidadap	Partially covered	Fully covered	Served
West	Cicendo, Bandung Kulon, Bojongloa Kaler	Partially covered	Fully covered	Served
South	Regol, Batununggal, Buahbatu, Rancasari	Partially covered	Partially covered	Underserved
East	Gedebage, Cibiru, Arcamanik, Cinambo	Outside the buffer	Partially covered	Critically underserved

Table 5 summarises the coverage result by spatial cluster. The city center is the only cluster served completely at both radii, and it is also the only cluster in which buffers overlap, which indicates redundancy of provision. The northern and western clusters move from partial to full coverage when the radius is widened from 3 km to 5 km, so their access is adequate but not optimal. The southern cluster remains only partially covered at both radii, while the eastern cluster lies entirely outside the 3 km buffer and is only partially reached at 5 km. The eastern and southern clusters are therefore the areas in which additional capacity produces the largest gain in coverage, and this classification is carried forward into the accessibility and gap analyses that follow.

Analysis of EVCS Accessibility to the Transportation Network

Accessibility plays a critical role in the effectiveness of electric vehicle charging infrastructure because it influences the ability of users to conveniently reach charging facilities. In transportation planning, accessibility reflects the level of connectivity between locations through the available transportation network and is commonly used as an indicator of service effectiveness and infrastructure performance. Within the context of Electric Vehicle Charging Station (EVCS) development, accessibility is closely associated with proximity to major road networks, urban activity centers, and the spatial arrangement of charging facilities across the city (Sani et al., 2023).

The accessibility assessment in this study was conducted using a Geographic Information System (GIS) through proximity analysis of arterial roads, collector roads, urban activity centers, and existing EVCS locations. Each spatial parameter was evaluated based on its relative distance to transportation infrastructure and activity hubs. Locations situated closer to major transportation corridors and high-intensity activity centers were assigned higher accessibility values because they provide more convenient access for electric vehicle users (Johnson, 2026; Longley et al., 2004).

The results indicate that most existing EVCS facilities in Bandung City exhibit relatively high accessibility levels. This condition is primarily attributed to their location along major transportation corridors, including Soekarno–Hatta Road, Asia Afrika–Braga–Lembong Road, Ahmad Yani Road, Ir. H. Juanda Road (Dago), Surapati Road, and Karawitan Road. These corridors represent areas with high traffic volumes and significant economic activities, making them attractive locations for EVCS deployment. Consequently, the current distribution pattern remains strongly associated with ease of access and expected facility utilization.

Several central districts, such as Sumur Bandung, Bandung Wetan, Coblong, Andir, and Lengkong, demonstrate the highest accessibility levels due to their strong connectivity to the primary road network and their proximity to commercial, educational, governmental, and tourism activities. In addition, these districts are located within areas that achieved high service coverage in the buffer analysis, indicating that charging infrastructure is concentrated in locations with intensive urban activities.

In contrast, districts located in the eastern part of Bandung City, including Gedebage, Cibiru, Cinambo, and parts of Arcamanik, exhibit lower accessibility levels. Although these areas have experienced substantial urban growth and residential expansion, the availability of EVCS facilities remains limited, resulting in greater travel distances and longer access times for electric vehicle users. This finding suggests that infrastructure development has not fully kept pace with urban expansion patterns in these districts.

From a demographic perspective, several districts with considerable population sizes and future development potential, such as Gedebage, Rancasari, and Cibiru, still experience relatively low accessibility to charging services. The imbalance between population growth and infrastructure provision indicates the need for a more equitable spatial allocation of EVCS facilities in future development plans.

These findings are consistent with previous studies emphasizing that proximity to transportation corridors and urban activity centers significantly influences the suitability of EVCS locations (Erbaş et al., 2018; Kenar et al., 2026). Furthermore, accessible charging infrastructure can reduce range anxiety and encourage wider adoption of electric vehicles by increasing user confidence in the availability of charging services (Neubauer & Wood, 2014; Ovchinnikov & Forestell, 2026).

Overall, the accessibility analysis demonstrates that EVCS infrastructure in Bandung City remains concentrated in central urban areas and major transportation corridors. Meanwhile, several eastern and southern districts continue to experience lower accessibility levels. These findings provide an important basis for the subsequent service gap analysis, which aims to identify areas with substantial demand but insufficient charging infrastructure provision.

Table 6

EVCS Accessibility Level by Region

Region/Sub-district	Proximity to Arterial Roads	Proximity to Activity Centers	Accessibility Level
Sumur Bandung	Very close	Very High	High
Bandung Wetan	Very close	High	High
Coblong	Near	High	High
Andir	Near	High	High
Lengkong	Near	Medium	High
Sukasari	Medium	Medium	Medium
Kiaracondong	Medium	Medium	Medium
Arcamanik	Far	Low	Low
Gedebage	Far	Medium	Low
Cibiru	Far	Low	Low
Cinambo	Far	Low	Low

Source: Author's GIS Analysis Results (2025).

Table 7

Distribution of EVCS Based on Main Road Corridors

Road Corridor	Number of EVCS	Percentage (%)	Characteristics
Jalan Soekarno Hatta	11	17,19	Main east–west arterial corridor
Jalan Asia Afrika–Braga–Lembong	9	14,06	Downtown, hotel and commercial areas
Jalan Surapati–PH Hasan Mustopa–AH Nasution	8	12,50	Central–east connecting corridor
Jalan Cihampelas–Sukajadi–Setiabudi	8	12,50	Trade, hotel and educational areas
Jalan Ahmad Yani	3	4,69	Business corridor and vehicle dealerships
Jalan Ir.H.Juanda-Martadinata	5	7,81	Dago area, hotels, and trade
Jalan Karawitan-Buahbatu-BKR	6	9,38	Southern and commercial areas
Other Corridors	14	21,88	Local distribution and supporting facilities
Total	64	100	

As presented in Table 7, the Soekarno–Hatta Road corridor accommodates the highest concentration of Electric Vehicle Charging Stations (EVCS), accounting for 11 facilities or 17.19% of the total charging infrastructure in Bandung City. This finding indicates that the deployment of EVCS has been strongly influenced by the presence of major arterial road networks, which provide high traffic volumes, strategic accessibility, and greater opportunities for facility utilization. The concentration of charging stations along primary transportation corridors reflects the tendency of infrastructure providers to prioritize locations with high mobility demand and strong connectivity to urban activities.

To assess the accessibility of EVCS facilities from the perspective of electric vehicle users, this study developed an Accessibility Index based on three key indicators: distance to arterial roads, proximity to the Central Business District (CBD), and travel time required to reach the charging station. These indicators were selected because they represent critical determinants of accessibility in urban transportation systems and directly affect user convenience, service efficiency, and the potential utilization of charging infrastructure. Previous studies have shown

that locations with better connectivity to major road networks and activity centers generally exhibit higher accessibility levels and greater demand for charging services (Neubauer & Wood, 2014; Ovchinnikov & Forestell, 2026).
The accessibility index is calculated using a weighted scoring method with the following equation:

$$IA = 0{,}4(JA) + 0{,}3(CBD) + 0{,}3(WT)$$

where:
1. IA = accessibility Index
2. JA = arterial road proximity score
3. CBD = city center proximity score
4. WT = travel time score

A weight of 0.40 was assigned to the arterial road proximity criterion, reflecting its dominant role in determining the accessibility of electric vehicle charging facilities. Locations situated near major transportation corridors generally provide better connectivity and higher potential utilization. Meanwhile, proximity to activity centers and travel time were each assigned a weight of 0.30, as both factors significantly influence user convenience, service efficiency, and the likelihood of charging station usage. The weighting scheme was designed to capture the relative importance of transportation accessibility and user demand in supporting effective EVCS deployment. The accessibility index values are then classified into four categories in Table 8.

Table 8
Classification of EVCS Accessibility Levels

Accessibility Index	Category
0,90 – 1,00	Very high
0,80 – 0,89	High
0,60 – 0,79	Medium
< 0,60	Low

The higher the accessibility index, the easier it is for electric vehicle users to reach the service station (EVCS). Conversely, a low index indicates that the EVCS location has limited access to the main transportation network and urban activity centers. The results of the accessibility index calculation are then used to identify areas with high service levels and areas that still need EVCS development to improve equitable access to electric vehicle services in Bandung City.

Table 9
Accessibility Analysis of Bandung City's EVCS (Complete)

No	EVCS	Artery Distance (m)	CBD distance (km)	Time (minutes)	Score	Category
1	PLN UID Jabar Asia Afrika	50	0,5	3	0,95	Very high
2	ICON Hub Braga Heritage	70	0,6	3	0,93	Very high
3	PLN Cikapundung	100	0,8	4	0,91	Very high
4	Wijaya Toyota Dago	150	2,2	6	0,88	High
5	Hyundai Ahmad Yani	120	2	5	0,89	High
6	Voltron Paskal Mall	80	1,5	4	0,92	Very high
7	PLN Karawitan	200	3,8	9	0,78	Medium
8	PLN Pasar Jamika	180	4	10	0,75	Medium
9	PLN Kiaracondong	220	5,2	12	0,7	Medium
10	PLN SMP 46 Cibiru	350	9	18	0,55	Low
11	PLN Hasan Mustopa	140	3,5	7	0,82	High

Source: author's GIS analysis results (2025), petaEVCS.id and OpenStreetMap data

Accessibility classification is determined based on the Accessibility Index value obtained by weighting the parameters of distance to arterial roads, distance to the Central Business District (CBD), and travel time to the EVCS location. Accessibility categories are divided into four classes: Very High (0.90–1.00), High (0.80–0.89), Moderate (0.60–0.79), and Low (<0.60). The higher the accessibility index value, the easier it is for electric vehicle users to reach the EVCS location.

EVCS Service Gap Analysis

A service gap analysis was performed to evaluate the disparity between the existing provision of Electric Vehicle Charging Stations (EVCS) and the potential demand for charging services across Bandung City. This assessment was developed by integrating the results of spatial distribution analysis, service coverage evaluation, accessibility assessment, and demographic characteristics at the district level. The combined analysis revealed that several central districts, including Sumur Bandung, Bandung Wetan, Coblong, Lengkong, and Andir, currently benefit from relatively adequate charging infrastructure. These districts exhibit higher service levels due to the concentration of EVCS facilities, broader service coverage, and superior accessibility to major transportation corridors and urban activity centers. In contrast, a number of districts located in the eastern and southern parts of Bandung City continue to experience lower service levels because of limited charging infrastructure availability and longer travel distances to the nearest charging facilities (Wang et al., 2026; Zhang & Tian, 2021)

The integration of spatial and demographic data further identified Gedebage, Cibiru, and Cinambo as districts with the most significant service deficiencies, categorizing them as critical gap areas. Meanwhile, Arcamanik and Rancasari were classified as high-gap areas due to their relatively high population potential and limited access to charging services. These findings indicate that the expansion of residential developments and urban activities in these districts has not been accompanied by proportional growth in charging infrastructure. If this imbalance persists, it may reduce accessibility to charging services, increase travel inconvenience for EV users, and potentially slow the adoption of electric vehicles in emerging urban growth areas. Consequently, districts classified as critical-gap and high-gap zones should be prioritized for future EVCS deployment to improve service equity, enhance infrastructure accessibility, and support the sustainable development of the electric vehicle ecosystem in Bandung City (Neubauer & Wood, 2014; Ovchinnikov & Forestell, 2026; Zhang & Tian, 2021).

Gap Analysis Based on Population Density

A comparison between the distribution of EVCS facilities and district-level population characteristics revealed that several highly populated districts remain underserved by charging infrastructure. Districts such as Gedebage, Rancasari, and Cibiru have experienced substantial residential growth and increasing urban activities, yet the availability of charging stations remains relatively limited(Badan Pusat Statistik, 2025). Consequently, residents in these districts may need to travel longer distances and experience lower accessibility to EV charging services than those living in central urban areas.

This finding indicates a mismatch between potential service demand and the current provision of charging infrastructure. Areas with larger populations generally generate higher mobility demand and therefore require greater support from transportation infrastructure. Previous studies have highlighted population density as one of the most important determinants in identifying priority locations for EVCS deployment, as densely populated areas tend to exhibit stronger charging demand and greater potential for electric vehicle adoption (Wang et al., 2025). Therefore, future EVCS development strategies should place greater emphasis on rapidly growing districts to promote a more equitable distribution of charging infrastructure and improve service accessibility throughout Bandung City.

Table 10

Gap Analysis Based on Population Density

Subdistrict	Density (people/km^2)	Number of EVCS	Service Level	Service Gap
Bojongloa Kaler	40.320	Low	Medium	High Gap
Cibeunying Kidul	27.315	Medium	High	Low Gap
Astana Anyar	26.914	Low	Medium	Moderate Gap
Batununggal	24.955	Low	Medium	Moderate Gap
Kiaracondong	23.166	Medium	Medium	Moderate Gap
Babakan Ciparay	20.831	Low	Medium	High Gap
Bandung Kulon	21.272	Low	Medium	High Gap
Rancasari	13.462	Medium	Low	High Gap
Cibiru	11.011	Low	Low	Critical Gap
Gedebage	4.808	Low	Low	Critical Gap

Gap Analysis Based on Accessibility

The accessibility assessment indicates that the majority of existing Electric Vehicle Charging Stations (EVCS) in Bandung City are strategically located along major transportation corridors and in proximity to urban activity centers, resulting in relatively high accessibility levels. While this spatial configuration improves convenience for users in central urban areas, it also contributes to a concentration of charging services within a limited geographic zone. Such a pattern reflects a development strategy that prioritizes areas with high mobility demand and strong transportation connectivity (Li et al., 2025b; Loew, 2017).

In contrast, several districts located in the eastern part of Bandung City continue to experience lower accessibility levels due to the limited availability of charging facilities and the greater distances separating users from existing EVCS locations. Consequently, electric vehicle users in these districts are required to travel longer distances and spend more time accessing charging services compared with users in central districts. This disparity suggests that the current distribution of charging infrastructure has not fully accommodated the spatial expansion of urban development and population growth (Wang et al., 2026; Zhang & Tian, 2021).

Overall, the findings demonstrate that EVCS accessibility in Bandung City remains heavily concentrated within the city center and along major arterial corridors. If future infrastructure development continues to focus primarily on these areas, disparities in service provision may become more pronounced, potentially reducing accessibility for residents in emerging urban growth zones. Moreover, inadequate access to charging facilities may contribute to range anxiety and discourage wider adoption of electric vehicles (Wahyudi et al., 2024; Zhang & Tian, 2021). Therefore, future EVCS planning should prioritize districts with relatively low accessibility but significant development potential in order to improve service equity, strengthen network coverage, and support the sustainable expansion of the electric vehicle ecosystem across Bandung City (Wahyudi et al., 2024).

EVCS Location Optimization Using GIS–AHP Approach

Determination of EVCS Location Optimization Criteria

The optimization of Electric Vehicle Charging Station (EVCS) locations was carried out by integrating Geographic Information Systems (GIS) with the Analytical Hierarchy Process (AHP) to identify priority areas for future charging infrastructure development in Bandung City. This integrated approach enables the incorporation of multiple spatial and socio-economic factors into a structured decision-support framework, thereby facilitating a more objective and data-driven evaluation of location suitability (Wang et al., 2026; Zhang & Tian, 2021).

The selection of evaluation criteria was based on a review of previous studies, the characteristics of urban development in Bandung City, and the findings obtained from the preceding spatial analyses. Four key criteria were considered in the optimization model: population density, regional accessibility, distance from existing EVCS facilities, and proximity to urban activity centers. These criteria were chosen because they collectively represent the major determinants of charging infrastructure demand, accessibility, service coverage, and potential facility utilization. Population density was included to capture potential charging demand, accessibility reflects the ease with which users can reach charging facilities, distance from existing EVCS supports a more balanced spatial distribution of infrastructure, and proximity to activity centers represents areas with high mobility intensity and greater charging requirements (Wang et al., 2025) By integrating these criteria, the optimization model provides a comprehensive basis for identifying locations that can maximize service effectiveness while promoting a more equitable distribution of EVCS infrastructure across Bandung City.

Criteria Weighting Using AHP

The AHP method was used to determine the relative importance of each criterion through a pairwise comparison process. The weighting results showed that population density was the most dominant factor in determining the location of EVCSs, followed by accessibility, distance to existing EVCSs, and proximity to activity centers.

Table 11
AHP Criteria Weight

Criteria	Weight
Population density	0,40
Accessibility	0,30
Distance from Existing EVCS	0,20
Proximity to Activity Centers	0,10
Total	**1,00**

The results of the consistency test show a Consistency Ratio (CR) value of 0.08, so the comparison matrix is declared consistent because it meets the requirement of CR < 0.10.

GIS Integration and Weighted Overlay Analysis

The AHP weighting results were then integrated into a Geographic Information System (GIS) using the Weighted Overlay Analysis method. Each parameter was reclassified on a suitability scale of 1–5, then multiplied by the AHP weight to generate a location suitability score.

The overlay process was performed on layers of population density, accessibility, distance to existing EVCSs, and activity centers. The integration produced a EVCS location suitability map that indicates the level of development priority in each area of Bandung City.

EVCS Location Optimization Results

The analysis shows that several sub-districts have a higher level of suitability than others. Gedebage, Cibiru, Rancasari, Arcamanik, and Cinambo sub-districts achieved the highest suitability scores due to a combination of high service needs, limited accessibility, and relatively large service gaps.

Table 12

EVCS Development Priority Ranking

Subdistrict	Suitability Score	Priority
Gedebage	4,72	Priority 1
Cibiru	4,58	Priority 1
Rancasari	4,41	Priority 2
Arcamanik	4,27	Priority 2
Cinambo	4,15	Priority 3
Kiaracondong	3,88	Priority 3
Sukasari	3,45	Priority 4
Coblong	2,10	Not a Priority

The analysis shows that several sub-districts have a higher level of suitability than others. Gedebage, Cibiru, Rancasari, Arcamanik, and Cinambo sub-districts achieved the highest suitability scores due to a combination of high service needs, limited accessibility, and relatively large service gaps.

Theoretical Interpretation and Comparison with Previous Studies

The spatial pattern identified in this study can be interpreted through the lens of classical location-allocation theory. In the p-median formulation, facilities are sited so as to minimise the aggregate weighted distance between demand nodes and the nearest facility, whereas in the maximal covering formulation the objective is to maximise the volume of demand captured within a predefined service radius. The observed concentration of charging stations in Sumur Bandung, Bandung Wetan, and Coblong corresponds closely to a maximal covering logic that has been applied to commercial rather than residential demand, because operators have prioritised locations offering long parking duration and high commercial footfall. The consequence is a network that performs well on the utilisation criterion but poorly on the equity criterion, since the demand nodes located in Gedebage, Cibiru, and Cinambo fall outside the covering radius of every existing facility. Interpreted in this way, the service gap identified in the preceding section is not a random deficiency but the predictable outcome of an objective function that omits population distribution.

From the perspective of public facility planning, charging infrastructure occupies an intermediate position between a purely commercial service and a public utility. Where a facility is treated as a commercial service, the location decision is governed by expected revenue; where it is treated as a public utility, the decision is governed by minimum service standards and spatial coverage obligations. The Bandung case indicates that the existing network has been shaped almost entirely by the first logic. The GIS-AHP framework applied in this study reintroduces the second logic by assigning 0.40 of the total weight to population density and 0.20 to distance from existing facilities, so that districts already served are penalised in the suitability score. This is consistent with the argument advanced in recent literature that spatial equity should be formalised as an explicit constraint or outcome metric rather than being left as a residual outcome of demand-driven investment (Li et al., 2025b). In terms of sustainable urban transportation, the relevance of this shift is that a charging network which is legible and reachable across the whole urban area lowers the perceived risk of switching to an electric vehicle, and it is this perceived risk, rather than vehicle price alone, that constrains adoption in emerging residential districts (Sheng et al., 2025).

Table 13 positions the present study in relation to recent GIS-based multi-criteria studies of charging station siting, and shows that the main point of differentiation is not the analytical technique but the explicit treatment of service equity as a criterion that drives the ranking.

Table 13

Positioning of the Present Study Relative to Recent GIS-Based Multi-Criteria Studies

Study	Case Area	Method	Criteria Emphasis	Treatment of Service Equity
Erbas et al. (2018)	Ankara, Turkiye	GIS with fuzzy AHP and TOPSIS	Environmental, geographic, urban, and transportation criteria	Not modelled explicitly
Kaya et al. (2022)	Erzurum, Turkiye	GIS-based multi-criteria decision making	Sustainability of shared electric mobility stations	Not modelled explicitly
Mahdy et al. (2022)	Winchester, United Kingdom	Multi-criteria decision analysis with imagery validation	Road network and parking availability	Partially addressed
Zhao et al. (2023)	China	GIS and multi-criteria decision making	Siting of solar-powered charging stations	Not modelled explicitly
Sheng et al. (2025)	Guangzhou, China	G2SFCA, MGWR, and random forest	Built environment determinants of accessibility	Measured but not used for siting
Spyropoulos et al. (2025)	Greek urban area	Hybrid GIS-MCDM	Urban planning and decarbonisation	Partially addressed
Li et al. (2025b)	Global, bibliometric	Review of 1,336 records	Development trends of GIS-MCDM	Identified as an unresolved research gap
This study	Bandung City, Indonesia	Spatial distribution, buffer, accessibility, gap analysis, AHP, and weighted overlay	Population density, accessibility, distance from existing EVCS, and proximity to activity centres	Modelled explicitly as a gap criterion that drives the priority ranking

Limitations of the AHP Method Relative to Other Multi-Criteria Approaches

The use of AHP in this study carries several methodological limitations that should be acknowledged. AHP relies on subjective pairwise judgements, so the resulting weights are sensitive to the composition of the expert panel, and a different panel may produce a different ranking even when the spatial data are identical. AHP also assumes that the criteria are mutually independent, which is questionable in this application because accessibility and proximity to activity centres are spatially correlated. In addition, the number of pairwise comparisons grows quadratically with the number of criteria, which restricts the practical expansion of the model, and the crisp nine-point scale does not accommodate the vagueness inherent in expert judgement. Alternative methods address these constraints in different ways, as summarised in Table 14. Recent reviews indicate that AHP and TOPSIS remain the most widely applied techniques in this field, but that fuzzy and hybrid designs are increasingly adopted in order to improve robustness (Kut & Pietrucha-Urbanik, 2024; Li et al., 2025b). Probabilistic formulations such as Bayesian network models have also been combined with GIS to represent uncertainty in siting decisions (Y. Zhang et al., 2022). A sensitivity analysis of the criterion weights, together with a comparative application of Fuzzy AHP, TOPSIS, ANP, and PROMETHEE to the same dataset, would therefore strengthen confidence in the priority ranking obtained here, and this is recommended as a direct extension of the present work.

Table 14

Comparison of AHP with Other Multi-Criteria Decision-Making Methods

Method	Principle of Weighting or Ranking	Main Advantage	Main Limitation	Relevance to EVCS Siting
AHP	Pairwise comparison with consistency testing	Transparent, easy to communicate, and integrates directly with weighted overlay	Subjective, assumes independence between criteria, and comparisons grow quadratically	Applied in this study
Fuzzy AHP	Pairwise comparison expressed with fuzzy numbers	Accommodates vagueness and uncertainty in expert judgement	Higher computational effort and sensitivity to the defuzzification rule	Preferable where expert judgement is uncertain
TOPSIS	Ranking by distance to	Effective for ranking a	Requires predefined	Complements AHP at

Method	Principle of Weighting or Ranking	Main Advantage	Main Limitation	Relevance to EVCS Siting
	the ideal and anti-ideal solutions	defined set of alternatives	alternatives and does not generate criterion weights	the ranking stage
ANP	Network structure permitting dependence between criteria	Captures interdependence among criteria	Complex matrix construction and demanding for respondents	Useful where accessibility and activity centres interact
PROMETHEE	Outranking based on preference functions	Avoids full compensation between criteria	Selection of preference functions and thresholds is subjective	Useful for comparing a small number of candidate sites

Economic Considerations in EVCS Development

The analysis presented here identifies the districts in which additional charging capacity is most needed, but a complete planning decision also requires an assessment of development cost, investment feasibility, and expected utilisation. The cost of a public charging station is driven mainly by the charger unit itself, the electrical connection and transformer capacity, civil works, land acquisition or lease, and the network and payment system, so that a fast charging installation is considerably more expensive than a standard alternating current unit. Utilisation is the principal determinant of feasibility, and it is precisely on this variable that the priority districts identified in this study differ from the central districts. Gedebage, Cibiru, and Cinambo currently generate lower charging demand than Sumur Bandung or Bandung Wetan, so an installation placed there would be expected to reach its break-even utilisation later. This produces a tension between spatial equity and commercial feasibility that the suitability model alone cannot resolve.

Table 15 sets out the cost and feasibility components that a subsequent financial appraisal should quantify, together with the policy instruments that may be used to close the viability gap in underserved districts. In the Indonesian context these instruments include the electricity tariff scheme applied to charging operators, the provision of land by the local government, and the co-location of charging facilities with existing public assets such as district offices, markets, and transport terminals, which reduces both land and connection costs. Comparable studies in other jurisdictions have shown that the combination of public land provision and staged capacity deployment is an effective means of extending charging networks beyond commercially attractive corridors (Mahdy et al., 2022). A staged deployment that begins with medium capacity units in Gedebage and Cibiru, followed by capacity upgrading once utilisation rises, would therefore limit the initial exposure of the operator while still delivering the equity objective identified by the model.

Table 15
Cost and Feasibility Components for the Appraisal of Priority EVCS Development

Component	Description	Implication for the Priority Districts
Charger investment	Unit cost varies by charging class, from standard alternating current units to fast and ultra-fast direct current units	Medium capacity units are recommended for the initial stage in Gedebage and Cibiru
Electrical connection	Transformer capacity, cabling, and metering, with cost rising sharply for high power installations	Co-location with existing PLN assets substantially reduces this component
Land and civil works	Land lease or acquisition, canopy, parking bay, and safety installation	Use of local government land at district offices and terminals lowers this component
Operation and maintenance	Periodic maintenance, network fees, payment system, and insurance	Largely fixed, so low utilisation raises the unit cost of service
Revenue and utilization	Determined by the number of charging sessions per day, the energy delivered, and the applicable tariff	Currently lower in the priority districts, which lengthens the payback period
Policy instrument	Tariff scheme for charging operators, land provision, and phased capacity upgrading	Required in order to close the viability gap between equity and commercial return

Interpretation and Planning Implications

The optimization analysis suggests that future Electric Vehicle Charging Station (EVCS) development in Bandung City should adopt a more balanced planning strategy that extends beyond traditional economic centers and major transportation corridors. While these locations continue to play an important role in supporting charging demand, the results indicate that several peripheral districts require greater attention to improve service equity. In particular, Gedebage and Cibiru emerged as the most suitable locations for future EVCS deployment due to their substantial service deficiencies, limited accessibility to existing charging facilities, and strong potential for urban growth. These characteristics make both districts strategic candidates for expanding the charging infrastructure network (Wang et al., 2025)

From the perspective of sustainable transportation planning, the integration of Geographic Information Systems (GIS) and the Analytical Hierarchy Process (AHP) provides a systematic framework for evaluating location suitability based on multiple criteria rather than relying solely on demand concentration or land availability. The application of this approach enables decision-makers to consider accessibility, population distribution, service coverage, and urban development patterns simultaneously, resulting in more objective and spatially balanced infrastructure planning (Wang et al., 2026; Zhang & Tian, 2021). Furthermore, improving charging infrastructure in underserved districts can enhance accessibility, reduce disparities in service provision, and strengthen the overall effectiveness of the EV charging network.

The findings also highlight the potential contribution of strategic EVCS expansion to broader sustainability objectives. Increasing the availability of charging facilities in priority areas may reduce user concerns regarding charging availability, commonly referred to as range anxiety, while simultaneously encouraging greater adoption of electric vehicles (Neubauer & Wood, 2014; Ovchinnikov & Forestell, 2026; Zhang & Tian, 2021). Consequently, the eastern and southern parts of Bandung City should be prioritized in future infrastructure development programs, as these areas exhibit the greatest need for additional charging facilities. Focusing investment in these locations is expected to support a more equitable distribution of services, improve urban mobility, and contribute to local energy transition and carbon emission reduction initiatives.

CONCLUSION

The current distribution of Electric Vehicle Charging Stations (EVCS) in Bandung City remains spatially uneven. Existing facilities are predominantly concentrated in central districts, particularly Sumur Bandung, Bandung Wetan, and Coblong, which function as major economic and administrative centers. Although these areas exhibit high service coverage, several peripheral districts, including Gedebage, Cibiru, Rancasari, and Arcamanik, continue to experience limited access to charging infrastructure. This finding indicates that the existing EVCS network has not yet achieved an equitable level of service across the entire urban area.

Accessibility and population density were identified as the most influential factors affecting EVCS development priorities. The analysis demonstrates that charging facilities are generally located near major transportation corridors and urban activity centers, resulting in higher accessibility levels. The AHP results further confirm that areas characterized by strong demand potential and convenient access should receive greater consideration in future infrastructure planning. The GIS–AHP optimization model successfully identified priority districts for future EVCS expansion. The results highlight Gedebage and Cibiru as the most suitable locations for additional charging infrastructure, followed by Rancasari, Arcamanik, and Cinambo. Expanding EVCS facilities in these districts is expected to improve service equity, strengthen charging accessibility, support wider adoption of electric vehicles, and contribute to sustainable urban transportation and energy transition initiatives in Bandung City.

Several directions are recommended for further research. The present model relies on static spatial data, so the integration of real-time traffic volume, origin and destination data derived from mobile network operators, and actual charging session records would allow the suitability score to reflect temporal variation in demand rather than an average condition. The application of artificial intelligence and machine learning, in particular spatially aware regression and ensemble models, would enable charging demand to be predicted at grid level and would reduce the dependence of the model on expert judgement. A comparative application of Fuzzy AHP, TOPSIS, and ANP to the same dataset, accompanied by a sensitivity analysis of the criterion weights, would test the stability of the priority ranking. Finally, coupling the siting model with the constraints of the electricity distribution network and with the financial appraisal components outlined in Table 15 would move the framework from a spatial suitability assessment toward a fully implementable investment plan for charging infrastructure in Bandung City.

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AUTHOR CONTRIBUTION STATEMENT

An An Anisarida: Conceptualization, methodology, investigation, data collection, formal analysis, data interpretation, writing – original draft preparation, and manuscript revision. An Syapril Janizar: Supervision, validation, methodology review, interpretation of findings, writing – review and editing, and final approval of the manuscript. All authors have read and approved the final version of the manuscript and agree to be accountable for all aspects of the work, ensuring the accuracy and integrity of the research.

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