

An ideal location selection of electric vehicle charging stations: Employment of integrated analytical hierarchy process with geographical information system

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ABSTRACT

Electric vehicle charging station identification is more essential in developing countries regions. Two major Middle Eastern capital cities are used to identify the EVCS which is important for environmentally friendly scenarios using the Analytical Hierarchy Process (AHP) and the Fuzzy-AHP (FAHP) in Baghdad (Iraq), and Riyadh (Saudi Arabia). With the help of GIS and multi-criteria decision analysis, suitable sites aimed at EVCSS are identified using twelve criteria. Based on the analysis very high suitable zones of Baghdad city have 179.99 km² (AHP), and 162.61 km² (FAHP), while Riyadh has 44.51 km² (AHP), and 34.27 km² (FAHP) respectively. Whereas, very low suitable areas for Baghdad have 552.47 km² (AHP), and 1596.74 km² (FAHP), while Riyadh has 518.43 km² (AHP), and 463.59 km² (FAHP) correspondingly. Karkh, Dora, Hurriya, Yarmouk, Binouk, and near the Baghdad international airport are more suitable for EVCSSs establish while in Riyadh Dhahrat Laban, Ash Shifa, Al-Sina'yah, Tuwaiq, Al-Olaya and Al-Murabba is more Suitable for EVCSSs. Green energy-based vehicle fuel is required for future development and reduction of fossil fuel use. Near the future, electric vehicles capture the maximum vehicle market, therefore identification of suitable sites for EVCSS plays a vital role in sustainable development.

1. Introduction

Environmental diversification is the most significant matter globally today (Dai & Du, 2023). It typically originates from the incessant and unrestrained hazardous emissions and air-related polluting fundamentals to the atmosphere because of the different actions of human societies (Khedher et al., 2022). To defend the environment and decrease the pollution in air, numerous nations have accepted strategies to inspire electric vehicle (EV) manufacture (Ghosh et al., 2021; Guo & Zhao, 2015; Hisoglu et al., 2023; Hosseini & Sarder, 2019; Pradhan et al., 2021; Zhang & Wei, 2023). Fossil fuels have continuously been the foremost human necessity source during past eras. The growth and transportation systems development in the current years have been extremely observed so that suitable retort to requirements of the people of separate communities in the field of the private and public transport was continually careful through representatives in this segment. If appropriate well-being circumstances for the people of civilization was one of the chief goalmouths of the government and also in each society, people can understand each administration's annoying to deliver

appropriate amenities in its sector of public transport (Ghodusinejad et al., 2022). The problem that has been elevated from the commencement with an outline of EVs as an additional spare for fossil-related cars, is charge stations placed for these vehicles it can even be thought that furthermore buying cost of these cars, which was the issue in increasing engineering, s also suitability for charge stations construction was the key issue in this industry growth (Al-Buraiki & Al-Sharafi, 2021; Elshurafa & Peerbocus, 2020). Since this charging type, different fossil-related vehicles was time-consuming and also the period of applying these vehicles was rather shorter than replicas with the fossil fuels, the verdict to building appropriate EVCS faces boundaries (Kaya et al., 2020). E.g., the time-consuming nature of this category of charging requires stations built in spaces with high safety, or this matter describes the time-consuming nature of the EVCSSs that can charge numerous vehicles concurrently (Elshurafa & Peerbocus, 2020; Guo & Zhao, 2015).

Since suitable site selection difficulties were a public problem, investigators have completed many analyses on this matter. Investigators have applied numerous mathematical programs, models, and also some

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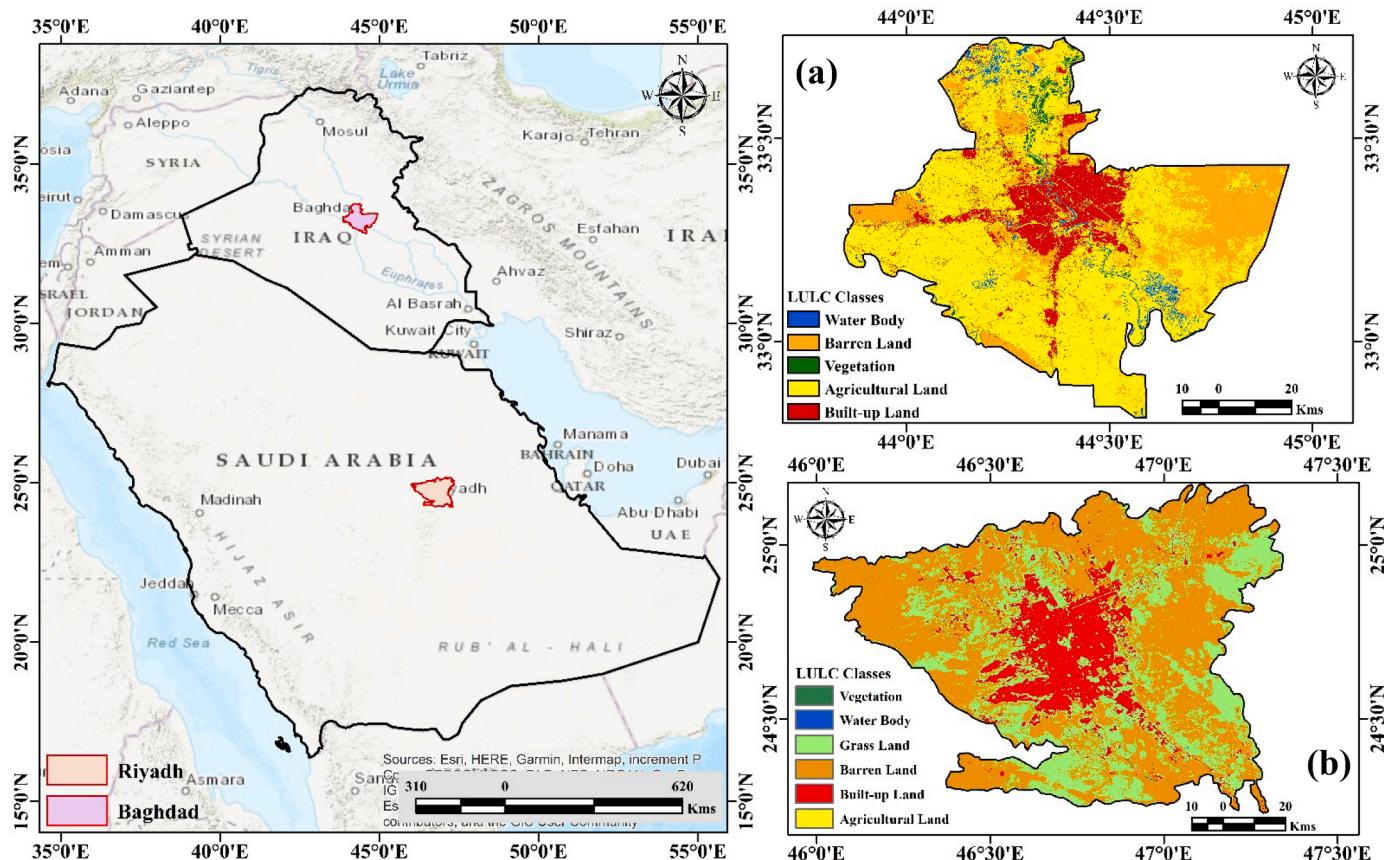


Fig. 1. Location map of the study area (Baghdad and Riyadh).

verbal descriptions (Al Zohbi, 2021; Almutairi, 2021; Charly et al., 2023; Rahman et al., 2020; Rane et al., 2023). In this unit, examination on the suitable site selection was examined. Formerly, EVCSs place selection analysis applying with GIS-based MCDM was examined. Lastly, the literature that investigates EVs was delimited. Researchers directed an analysis in Taiwan applying Integer programming to find EVCSs for scooters (Wang et al., 2022). Another researcher used AHP, GIS, ground-penetrating radar, and also vertical electrical sounding techniques to select maximum appropriate landfill place. As an analysis outcome, the most suitable three positions are resolute for the landfill sites (Osra & Kajjumba, 2020). Researchers directed a location assortment analysis for the inland-related nuclear power plant (Wu et al., 2020). The type-2 of the fuzzy PROMETHEE II and GIS are applied for this analysis. The substitute termed S8 originated as the most appropriate region in nine different parts. Researchers resolved a zone identification difficulty for a car sharing station (Li et al., 2022). Lengthy with the MULTIMOORA is applied in analysis with the fuzzy environment. Furthermore, there were other investigations for the site selection like organic farming (Mishra et al., 2015), renewable energy systems (Aydin et al., 2013), dangerous waste removal (Gómez-Delgado & Tarrantola, 2006), sustainable shelter (Song et al., 2019), and bike portion positions (Erbaş et al., 2018). These EVs were affected based on the charging capacity of the battery and the ability to maintain and control the battery charging. The EVs charging regulator plans were immobile under conversation. These vehicles were completely reliant on rechargeable batteries and have suffered from battery drainage, security issues, and energy management, (Qureshi et al., 2021). Though, a crucial encounter was how to express the flexible plans for corresponding the EVCSs and PVNBs based on the PVNBs power group, the EVCSs power request, period, and geospatial location, to brand the PVNBs power can be brought to the suitable EVCS and spent (Pan et al., 2020; Zhang et al., 2024)

Some analytical outcomes applied entropy and also the Gray Relation Analysis-VIKOR (GRA-VIKOR) approaches to control the greatest appropriate EVCS site among the five substitute EVCSs in Tianjin (Zhao & Li, 2016). In the analysis, four of the main and 13 sub-criterions are observed. The weighting applied an information technique and also with substitutions are graded rendering to the standards through the GRAVIKOR technique. The analytical outcomes designated the most appropriate between four alternative EVCSs in the Changping area based on criteria. The limits affecting EVCS place are determined and also weighted through a team of around five experts (Guo & Zhao, 2015). Additional researchers formed the Pythagorean fuzzy VIKOR (PF-VIKOR) model to examine EVCSs suitability and efficiency projected in the Shanghai section (Cui et al., 2018). The alternatives evaluation to applied Pythagorean fuzzy values (PFVs). Four alternative EVCSs shaped as model outcomes are ranked with TOPSIS and VIKOR approaches attractive into the thought social, economic, engineering feasibility, and environmental factors. Investigators assessed the most appropriate alternative EVCS sites for Tianfu province. Seeing four chiefs and also 14 sub-criterions, the best six substitute EVCSs are resolute from around 30 diverse replacements. The criteria weighting applied entropy and ranking applied the ELECTRE technique among alternatives (Xu et al., 2018). Three chief and around 11 sub-criterions are taken obsessed by the deliberation and ranking applied fuzzy TOPSIS technique. Many investigators assessed the most appropriate EVCS sites and also the sizing with the mixed-integer non-linear (MINLP) optimization method, which is resolved by applying the genetic algorithm technique (Sadeghi-Barzani et al., 2014). The greatest EVCS-suitable locations are observed with this model. Alternative analysis observed that the present and maximum appropriate alternative of the EVCS sites in the Ankara area. Based on the literature review and also the expert thoughts, 15 criteria are chosen for the EVCS location assortment (Erbaş et al., 2018). These criteria are weighted through the AHP technique (Ahmed et al.,

2016; Colak et al., 2020). The criterion stratification is made through GIS and the suitability diagram is designed. Possible sites for the EVCSSs are determined and also substitute EVCSSs are ranked by applying the TOPSIS technique.

The two distinct investigative parts integration, MCDM and also GIS, can benefit discourse tests that rise once spatial datasets and assessing criteria (Ekmekcioğlu et al., 2021; Halder et al., 2022). The GIS allows spatially positioned database integration obsessed by the environment for resolving difficulties, while the MCDM includes prioritizing, assessing, and also designing substitute verdicts by applying numerous methods and measures in complex decision-making difficulties. The GIS-based MCDM methods were usually work for the solving of geo-spatial decision difficulties, where there was a requirement to control the greatest likely choice between change sets (Halder et al., 2023; Thangaraj et al., 2022). This process can be multifaceted because multiple issues affect the selection procedure. The MCDM delivers an outline for measuring these factors and also arriving at an optimal pronouncement (Halder & Bandyopadhyay, 2022). The FAHP and AHP are widely applied for location assortment and susceptibility mapping in different parts of the globe (Altintasi & Yalcinkaya, 2022). Therefore, based on the literature review and previous application, Baghdad (Iraq) and Riyadh (Saudi Arabia) both capital cities of the two countries are applied for the site selection of EVCSSs. Globally most of the countries are going to renewable energy sources for vehicle use and those cities are more important for both counties where electric charging stations are increasing the environmentally friendly vehicles and improving the air quality in Baghdad and Riyadh cities. The novelty of the research is to find out the EVs area in Riyadh and Baghdad which is more recent work and not done previously with different two types of methods like AHP and F-AHP, while it helps to build an appropriate EVs station in both important middle east cities. ArcGIS v10.8 and Google Earth Engine (GEE) platform applied for calculating and extracting criteria. Based on the literature review twelve criteria were applied to identify EVCSSs in both countries, like amenities, roads, parking areas, railways, bus depots, and many others. The novelty of the research is to novelty of the suitable locations for EVCSSs in Baghdad and Riyadh using AHP and FAHP methods, which is the first time to identify the two major cities. That information is improving the possibilities to build appropriate sites for vehicle charging stations. Green energy can reduce air pollution and increase environmental health towards sustainable development.

2. Study area

EVs were likewise excused from numerous duties and taxes, creation them the cost-effective choice aimed at the clients. With cumulative apprehension about finished changing climate, there was a rising essential to decrease carbon emissions. The EVs were the eco-friendly substitute for outdated gasoline-powered cars. The main far was the nation's capital, Baghdad, with around 7.5 million population. Baghdad is situated in the center of Iraq. The Baghdad municipality area reached around 870 km², while the complete analysis zone controlled around 5097 km² in this site selection examination. Advantages characteristics study zone were: fundamentally great extremism in little precipitation, the temperature, high sun brightness, and low relative humidity (Hashim et al., 2023). The Baghdad city is situated between 33.3152°N, and 44.3661°E, while the average elevation is 34 m. This part is under the hot desert climate (*BWh*), considered through low relative humidity, extreme temperatures, high solar radiation, and also little precipitation (Fig. 1). The capital city of Iraq, Baghdad is the main decision-making center and principal urban centres in the middle east. It was similar careful Iraq's administrative center and biggest economy, which was nearly enclosed by built-up zones in the central part (Tao et al., 2022). The Baghdad urban sprawl protracted through agricultural conversion and also barren zones to meet the covering emergency of an enlarged populace and lack of maintainable city development. The capital city of Saudi Arabia, Riyadh is located in the arid environment of Nadj Plateau

Table 1

Details about the datasets used for EVCs estimation for Baghdad and Riyadh city.

Datasets	Criteria Applied	Websites/Software
Amenities	ATM, School, Bank, Restaurant, Hospital, Café, etc.	Google Earth Pro
Fuel/gas Stations	Fuel or Gas for vehicles	
Road	Accessible Area	https://extract.bbbike.org/
Commercial Office	Near commercial office	
Railway/Metro	Accessible Area	
Bus Dept	Accessible Area	
Parking Area	Vehicles parking	
Vegetation (NDVI)	NDVI (Landsat Image)	https://earthexplorer.usgs.gov/
Water Body (NDWI)	NDWI (Landsat Image)	
Built-up Land	Classification Map (Landsat Image)	
Carbon Monoxide (CO)	Pollution from vehicles (Sentinel-5p)	Google Earth Engine (GEE)
Slope	SRTM DEM data	https://earthexplorer.usgs.gov/

region. Once a minor enclosed urban, it has established interest in the fluctuating metropolis completed around the years particularly throughout the oil boom period from 1970 to 1990. It was around 400 km from the Persian Gulf's West coast and also about 1000 km from the Red Sea's East part of the coast. It lies at around latitude of 24.38° N and a longitude of 43.46° E and Riyadh's elevation is 612 m above MSL. It was the main communication route crossroads; its relations Arabian Gulf area with the Levant and Red Sea and also with Iraq (Southern Arabia). Around nearest businesses aims to improve Saudi Arabia's motorized network, through partnership with EV corporations, by supplying essential charging stations to encounter upcoming mandate (<https://www.arabnews.com/node/2387536/business-economy>). The complete examine zone of Riyadh in this analysis is 8691 km² for site suitability analysis for EVCSSs. Furthermore, its performance as a transit hub and central point among Arabian Peninsula countries in specific and in West Asia (Elshurafa et al., 2022; Kammona et al., 2021). The high population popularity the Riyadh city was natural growth outcome and global migration that transports people of numerous identities and cultures here. It improves meaning of the Riyadh city in terms of multiculturalism or cultural stalemates in the Arabian Desert's heart location. In the early 1900s, Riyadh city, though taking a long antiquity, was a minor tribal reserve while people are alive a tribal existence.

3. Materials and methodology

3.1. Applied database

Electric vehicle charging station identification is essential for sustainable development and fossil fuel-based pollution generated from the vehicles. Different two types of methods AHP and also the Fuzzy-AHP were applied to identifying EVCs in two different capital cities of Middle Eastern countries like Iraq (Baghdad) and Saudi Arabia (Riyadh). Based on the literature review and previous analysis, twelve criteria are selected for both countries. Those criteria were classified based on the vector and raster datasets and collected from different methods. Some analytical software like ArcGIS, QGIS, and Google Earth Engine (GEE) platforms are applied to identify the EVCs on those cities. Mainly three types of satellite datasets are applied Landsat 8 (vegetation, water bodies, and built-up lands), Sentinel 5p (CO), and SRTM DEM (slope) in this investigation (Halder et al., 2023). Some vector datasets like amenities, parking areas, fuel stations, commercial offices, and road and railway information were collected from Google Earth Pro and one website (<https://extract.bbbike.org/>). The entire dataset's related information is Added in Table 1. (For the Carbon Monoxide (CO) identification, Sentinel 5p and GEE platform are applied in this analysis (Fig. 2).

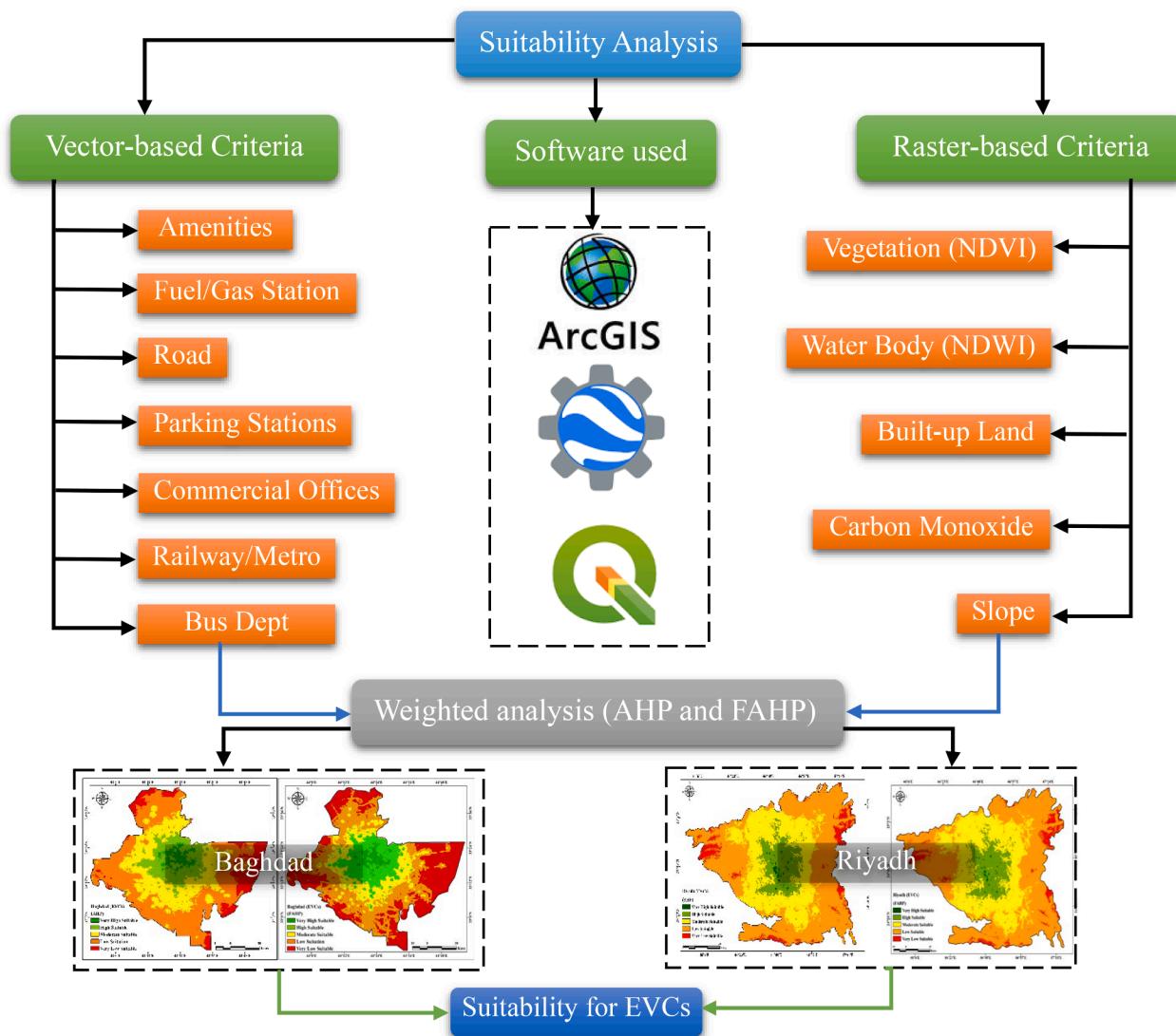


Fig. 2. Adopted methodology for EVCs identification of Baghdad and Riyadh.

Table 2

The essential scale and its explanation for pairwise comparison matrix (Saaty 1980).

importance rank	Definition	Explanation
1	Equal importance	Two criteria enrich equally to objective criteria
3	Low importance of one over another	Judgments and experience slightly favour one criterion over another
5	Strong or essential importance	Judgments and experience slightly favour
7	Established importance	A criterion is strongly favoured and its dominance established in practice
9	Absolute or high importance	The evidence favouring one criterion over another is of the highest probable order of affirmation
2,4,6,8	Intermediate values between the two adjacent importance or judgments	When adjustment is needed
Reciprocals	If criteria i has one of the above numbers designated to it when compared with criteria j, then j has the reciprocal value when compared with i.	

3.2. AHP method

This inspection used AHP and also the Fuzzy-AHP events for the EVCS inspection. In this present examination, twelve criteria were applied for EVCS suitable site selection in Baghdad and Riyadh. This contributory effect is like amenities, parking areas, roads, railway, bus stand, commercial offices, built-up land, vegetation, water bodies, CO, and slopes. The factor restrained here is preliminary subjects, which can be collected naturally from available indications and in the field. The thematic datasets layer for each criteria charting is prepared in the GIS-based request stage, remote sensing (RS) datasets, and also the field survey datasets (Table 2). The analytical hierarchy process (AHP) is a semi-quantitative method in which selections are kept using weights through a pair-wise comparison method without inconsistencies in the decision-making process (Saaty, 1990, 2005). AHP covers of subsequent five phases like (1) disruption choice complications into constituent matters (ii) groundwork of these criteria in hierarchic teaching (iii) development of numerical values (Saaty, 1977) to regulator relative location of each criterion version to their meaning (iv) comparison matrix system and (v) all criteria weight normal (Yaseen, 2024). Applying AHP compensations was an expend-based method in the EVCSs examination are, (1) all indications linked to EVs can be complicated in the conversation process. (2) discovery is prearranged so

Table 3

Pairwise comparison matrix for multi-criteria decision analysis for Baghdad.

Criteria	Amenities	Fuel/Gas Station	Road	Parking Station	Commercial Offices	Railway/Metro	Bus Dept	Vegetation	Water Bodies	Built-up Area	Carbon Monoxide	Slope
Amenities	1	4	6	4	4	5	4	4	6	4	5	6
Fuel/Gas Stations	0.25	1	2	3	1.5	3	3	4	4	4	3	5
Road	0.167	0.50	1	4	3	3	2	4	4	4	4	5
Parking Station	0.25	0.333	0.25	1	3.5	2.5	3	3	3	3	4.5	4
Commercial Offices	0.25	0.667	0.333	0.286	1	1.5	2	1.5	2	4	3.5	4.5
Railway/Metro	0.20	0.333	0.333	0.4	0.667	1	1.5	1.5	2	3	4	3.5
Bus Dept	0.25	0.333	0.5	0.333	0.50	0.667	1	2	2	2	3	3.5
Vegetation	0.25	0.25	0.25	0.333	0.667	0.667	0.5	1	2.5	2.5	2.5	3
Water Bodies	0.167	0.25	0.25	0.333	0.50	0.50	0.5	0.4	1	4.5	3.5	2.5
Built-up Area	0.25	0.25	0.222	0.286	0.25	0.333	0.4	0.4	0.222	1	2	1.5
Carbon Monoxide	0.20	0.333	0.25	0.222	0.286	0.25	0.333	0.4	0.286	0.50	1	2.5
Slope	0.167	0.20	0.2	0.25	0.222	0.286	0.286	0.333	0.4	0.67	0.4	1
Total	3.4	8.45	11.589	14.444	16.0912	18.702	18.519	22.533	27.408	34.67	36.4	42

that all evidence is occupied into clarification (3) discussion instructions are based on specialist's evidence and participation, (4) when a contract is affected, weights for altogether pertinent criteria become automatically through eigenvector comparison matrix control, and (5) constancies in the decision process can be observed using consistency index standards recognized by the researcher Saaty (Saaty, 1977). Unlike detectives have used the AHP method in EVCSs zonation in varied shares internationally. Numerous detectives also applied AHP and the Fuzzy-AHP to assign weight criteria for composed causal criterion and dissimilar causal criterion lessons. The fuzzy-AHP structure process obscures establishment comparison matrix, combination of many rulings, and also the extent of fuzzy weights constancy.

3.3. Weighted calculation applying different approaches

3.3.1. Pairwise comparison method (AHP)

This technique typically is a comparison procedure for criteria that are measured at a period in footholds of their relative position to the judge which of all criteria are favored, or has convinced numerical stuff better quantity, or whether or not two different objects are equivalent (Ahmed et al., 2016; Colak et al., 2020). This technique is recognized by the researcher Saaty (Saaty, 2008) in an AHP applications setting. This technique covers three chief stages like, pairwise comparison matrix

group, calculation of every weight, and also consistency ratio (CR) estimate (Doost & Yaseen, 2024).

3.3.2. Pairwise comparison matrix analysis

This matrix contrasts two dissimilar criteria in solitary dated. It contrasts the column constituent from the noise component, capitals how importantly important column constituent from approximation row component of output results (Radwan et al., 2019; Vahidnia et al., 2009). Today this was an amount attainment from around 1–9, which is location strength. E.g., assuming there are two different standards like X and Y. Uncertainty, standard X is exactly as important as Y, location standards might be around 1 therefore, diagonal rudiments of the matrix would unceasingly 1. Doubt, standard X is extremely important than Y, directory standards might 9 (Table 2). In this technique, contrast every distinct standard with the further criterion. If standards are prepared on the base of the stimulus on the output diagram, then indispensable to the influence $n = \frac{(n+1)}{2}$ comparative location standards.

3.3.3. Criterion weights design

In this stage, separate weights criteria are deliberate. First of every, standardized eigenvalue matrix is shaped, each matrix standard is disconnected through the sum of its pillar, and every row mean of this legalized eigenvalue matrix is the weight of that exact standard.

Table 4

Standardized matrix and weighted distribution for multi-criteria decision analysis for Baghdad.

Criteria	Amenities	Fuel/Gas Station	Road	Parking Station	Commercial Offices	Railway/Metro	Bus Dept	Vegetation	Water Bodies	Built-up Area	Carbon Monoxide	Slope	Weight
Amenities	0.294	0.473	0.518	0.277	0.249	0.267	0.216	0.178	0.219	0.115	0.137	0.143	0.257
Fuel/Gas Stations	0.074	0.118	0.173	0.208	0.093	0.160	0.162	0.178	0.146	0.115	0.082	0.119	0.136
Road	0.049	0.059	0.086	0.277	0.186	0.160	0.108	0.178	0.146	0.130	0.110	0.119	0.134
Parking Station	0.074	0.039	0.022	0.069	0.218	0.134	0.162	0.133	0.109	0.101	0.124	0.095	0.107
Commercial Offices	0.074	0.079	0.029	0.020	0.062	0.080	0.108	0.067	0.073	0.115	0.096	0.107	0.076
Railway/Metro	0.059	0.039	0.029	0.028	0.041	0.053	0.081	0.067	0.073	0.087	0.110	0.083	0.062
Bus Dept	0.074	0.039	0.043	0.023	0.031	0.036	0.054	0.089	0.073	0.072	0.082	0.083	0.058
Vegetation	0.074	0.030	0.022	0.023	0.041	0.036	0.027	0.044	0.091	0.072	0.069	0.071	0.050
Water Bodies	0.049	0.030	0.022	0.023	0.031	0.027	0.027	0.018	0.036	0.130	0.096	0.060	0.046
Built-up Area	0.074	0.030	0.019	0.020	0.016	0.018	0.022	0.018	0.008	0.029	0.055	0.036	0.029
Carbon Monoxide	0.059	0.039	0.022	0.015	0.018	0.013	0.018	0.018	0.010	0.014	0.027	0.060	0.026
Slope	0.049	0.024	0.017	0.017	0.014	0.015	0.015	0.015	0.015	0.019	0.011	0.024	0.020
	1	1	1	1	1	1	1	1	1	1	1	1	1

Table 5
Estimation of the consistency ratio for Baghdad.

Criteria	Amenities	Fuel/Gas Station	Road	Parking Station	Commercial Offices	Railway/Metro	Bus Dept	Vegetation	Water Bodies	Built-up Area	Carbon Monoxide	Slope	Total	Cr
Amenities	0.257	0.543	0.804	0.426	0.303	0.312	0.233	0.200	0.274	0.114	0.131	0.118	3.716	14.448
Fuel/Gas Stations	0.064	0.136	0.268	0.320	0.114	0.187	0.175	0.200	0.183	0.114	0.078	0.098	1.937	14.277
Road	0.043	0.068	0.134	0.426	0.227	0.187	0.117	0.200	0.183	0.128	0.105	0.098	1.916	14.296
Parking Station	0.064	0.045	0.034	0.107	0.265	0.156	0.175	0.150	0.137	0.100	0.118	0.078	1.429	13.402
Commercial Offices	0.064	0.090	0.045	0.030	0.076	0.094	0.117	0.075	0.091	0.114	0.092	0.088	0.976	12.879
Railway/Metro	0.051	0.045	0.045	0.043	0.051	0.062	0.087	0.075	0.091	0.086	0.105	0.069	0.810	12.954
Bus Dept	0.064	0.045	0.067	0.036	0.038	0.042	0.058	0.100	0.091	0.071	0.078	0.069	0.760	13.031
Vegetation	0.064	0.034	0.034	0.036	0.051	0.042	0.029	0.050	0.114	0.071	0.065	0.059	0.648	12.972
Water Bodies	0.043	0.034	0.034	0.036	0.038	0.031	0.029	0.020	0.046	0.128	0.092	0.049	0.579	12.678
Built-up Area	0.064	0.034	0.030	0.030	0.019	0.021	0.023	0.020	0.010	0.052	0.029	0.052	0.362	12.685
Carbon Monoxide	0.051	0.045	0.034	0.024	0.022	0.016	0.019	0.020	0.013	0.014	0.026	0.049	0.333	12.729
Slope	0.043	0.027	0.027	0.027	0.017	0.018	0.017	0.017	0.019	0.019	0.020	0.020	0.259	13.206

Maximum Eigenvalue (λ_{max}) = 13.29637244.

$$n = 12.$$

$$\text{Consistency index (CI)} = \frac{(\lambda_{max} - n)}{(n - 1)} = 0.11785204.$$

Random index (RI) = 1.54.

$$\text{Consistency ratio (CR)} = \left(\frac{CI}{RI} \right) = 0.079629757.$$

3.3.4. Consistency ratio (CR) estimate

In this phase, course weighted sum is determined, through cumulative weight for the first standard period's first column of a single pairwise comparison matrix technique (Al Garni & Awasthi, 2017; Karmakar et al., 2021). The technique of whole weighted vector sum is intended through a convincing process. Finally, the sum of the vector weighted is detached through consistent criterion weight in a certain order, initially the sum of weighted division through the first standard weight and finally detached through the last standard weight to develop a consistency vector (CV). The city of Baghdad (Tables 3–7) and Riyash (Tables 8–11) areas are applied to calculate the EVCS using AHP and FAHP methods.

The CI , when λ_{max} is observed like the highest calculated matrix eigenvector and the n denotes the total criterion's amount. Random index (RI) was the mean consistency index value contingent on matrix instruction expected by the researcher Saaty (Table 6).

$$CI = \frac{\sum (\lambda_{max} - n)}{(n - 1)} \quad (1)$$

The AHP is foreseeable through CR which is unhurried through the equation helps to categorize the adapted balanced pairwise comparison matrix illogicality documented originated on skilled or knowledge ruling. The CR values <0.1 is dependable pairwise matrix symbol. The RI values are certain predefined quantity; those are change with the criterion number used.

$$CR = \left(\frac{CI}{RI} \right) \quad (2)$$

where RI is mentioned as random index.

3.4. Fuzzy-AHP

The Fuzzy-AHP method was a process applied to solve difficulties in numerous fields like economic, social, and organizational sciences (Kaya et al., 2020). The Fuzzy-AHP was distinct as the progressive analytical method established by the researcher Saaty's AHP technique (Saaty, 1990). Contempt AHP consistency in multi-criteria decision-making difficulties, the conservative AHP technique was not carefully reliable in uncertain and fuzzy environments. In the traditional AHP technique, decision creators have problems because they apply numerical standards while creating their assessments. The FAHP method has been established to overawe traditional AHP inadequacy and near yield additional operative resolutions to difficulties in uncertain surroundings (Ekmekcioğlu et al., 2021). Similarly, when criteria number and substitutes are high, AHP implementation can generate negative properties in pairwise comparison matrix terms. The FAHP technique was additionally appropriate and extra accurate since it applies linguistic variable stars in a pairwise comparison matrix. An alteration planned a technique applying three-sided fuzzy numbers in the pairwise comparison matrix in FAHP (Al Garni & Awasthi, 2017; Aydi et al., 2015). The query occupied into the thought for decision makers side to make pairwise comparison matrix is, "which was captivating into the account additional significance through decision-makers in the selecting EVCS site, and how significantly additional significant was it concerning gratification with EVCSs site?" decision creators' squad resolute position criteria degree applying for the fuzzy triangular numbers.

3.5. Criteria

3.5.1. Amenities

The amenity's proximity plays a vital playing role in EVCS application through refining suitability, convenience, consciousness, and residence time for EV drivers. When EVCSs were situated close to amenities like shopping centres, ATMs, Hospitals, restaurants, or also movie auditoriums, it developed additional suitable aimed at the EV chauffeurs to

Table 6Random inconsistency indices (RI) for $n = 15$. (Saaty, 2003).

Order	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
R.I.	0	0	0.52	0.89	1.11	1.25	1.35	1.4	1.45	1.49	1.52	1.54	1.56	1.58	1.59
Frist Order Difference	0	0.52	0.37	0.22	0.14	0.1	0.05	0.05	0.04	0.03	0.02	0.02	0.02	0.02	0.01

vehicle charge though those people are involved in additional happenings. This can upsurge charging station practice, as drivers were additional likely to apply them if they were situated in convenient sites. The EV chauffeurs might essential a near delay for their car to charge, those can receive wherever from around 30 min to numerous hours depending on the EVCSs category and also the vehicle's battery volume. The amenities juxtaposition can support type delay time additional pleasant aimed at the drivers, who might select to devote time at neighbouring stores or restaurants although their automobile charges (Figs. 3 and 4). The EVCSs situated neighbouring facilities can be additional nearby to the wider variety of drivers, counting those who might go without admission to EVCSs in their hometowns or office. The designated metropolises have different amenity's sites consequently approximately proximities were intended for suitability equal to the EVCSs. Both metropolises have high appropriate of EVCSs below 0.5 km from all amenities.

3.5.2. Fuel/Gas stations

The fuel/gas station proximity can similarly influence charging stations appropriateness of happening an EV appropriateness diagram. The attendance of petrol pumps in charging stations neighbourhood can upsurge suitability for the EVs charging operators, as those people can brand apply charging time to replenish their fuel reservoirs also. Consequently, the obtainability of both EVCSs and also fuel/gas positions in near juxtaposition can improve the general appropriateness of an EV charging substructure in Baghdad and Riyadh. Fuel stations are more important for EVCS identification. Because most unplanned urban areas are heterogeneous and very hard to find vacant places for newly established EVCS, therefore existing fuel station is an alternative location for these issues. Therefore, fuel or gas stations play a vital role. Both cities have very high suitability under 1 km of every existing fuel station (Figs. 3 and 4).

3.5.3. Road

The detachment to the roads was the additional significant influence that can distress EVCSs appropriateness in Baghdad and Riyadh. The charging stations' accessibility was an important cause of their application, and also the distance to the roads can influence their appropriateness. Analysts renowned also the EVCSs situated earlier on highway roads and main roads may be additional nearby and convenient for the EV customer, as they can decrease portable distance and time to EVCSs. Furthermore, road proximity can similarly influence charging positions connectivity to the power grid, which can touch those appropriateness (Figs. 3 and 4). The charging station site relative to the power grid can influence electricity distribution prices and establish EV charging feasibility infrastructure. Mostly highways and streets were additional significant than a sub-street site for the EVCS suitability because of the sub-street have additional overfilled than highway or foremost street. Both cities have very high suitable under 0.5 km and high suitable under 0.5–1 km.

3.5.4. Parking stations

The parking station's obtainability was a significant thought for the EV customer when choosing to charge positions, as those people essentially home toward the parking areas and also charge their cars. The analyst calculated the EVCSs situated earlier to the parking parts, like the public space heaps or devoted EV areas parking areas acnes, might be additional suitable and nearby for the EVs customer (Figs. 3 and 4). The incomplete EVCS availability can lead to extended to-come

times and condensed usage, which can dishearten EV acceptance. Neighbouring parking part was additionally appropriate for the EVCS, even in parking parts decrease EV charging time. The greatest people can charge vehicles while parking time and save extra time. In these two main cities under 1 km is very highly suitable for EVCS.

3.5.5. Commercial office

Marketable offices are inclined to have more high attentiveness of the workers who travel to the exertion, and numerous of these workers might apply EVs for their everyday travel. Consequently, EVCSs availability neighbouring profitable workplaces was vital to provision mounting requests for the EVCSs. Installation of EVCSs in zones with a high attentiveness of commercial offices can ease the EV charging aimed at workers who travel to the workplace. Altogether commercial offices have additional vehicles, and those regions are more suitable for EVCS because many vehicles are parked near offices (Figs. 3 and 4). People can charge their vehicles during office time in the parking areas. Based on the areal condition Baghdad has 2 km of very high suitability zone while Riyadh has 1 km of very high suitability area.

3.5.6. Railway/Metro

Railway or metro stations were the main transportation centres, and people often apply these positions to portable to and from numerous sites. Consuming the EVCSs situated near these positions can upsurge convenience and suitability for the EVs drivers, particularly those people who trust public transport. They can entice big amount of people, counting tourists and travellers, and they could upsurge purchasers improperly for the EVCSs situated neighbouring. This could be principal toward the enlarged income aimed at EVs charging position operative (Figs. 3 and 4). Metro or railway station parts were similarly vigorous for the EVCS because those parts were additional nearby for resident people to the transit. Baghdad has 2 km of very high suitable for EVCS while Riyadh has 1 km near railway lines. For both cities, under the 1 km buffer zone is very high suitable for EVCS.

3.5.7. Bus stand

Bus depots were frequently situated in the central parts and also can help as transport centers for the resident buses. Consuming EVCSs situated near these garages can upsurge convenience and suitability aimed at the EVs drivers, particularly if they are applying for public transport. The bus garages can entice a great amount of people, counting tourists and commuters, which could surge purchasers improperly for the EVCS situated neighbouring (Figs. 3 and 4). This could be principal to augmented income aimed at EVs charging position workers. Numerous bus garages have huge navies of the buses that function on the electric power. Placement EVCSs neighbouring bus depots could be helpful for charging these navies, as it would deliver a suitable and central site aimed at recharging. The local partitioning guidelines might have exact supplies or limitations on the site of the EVCS neighbouring bus garages. Baghdad has 2 km of very high suitable for EVCS while Riyadh has 1 km near railway lines.

3.5.8. Vegetation (NDVI)

Parts with a better greenery abundance can designate additional wealthy and established groups (Doost & Yaseen, 2023), which were additionally probable to have a higher degree of the EVs possession. Consequently, parts with higher NDVI standards, which designate greater green space thickness, might be additional good-looking to the EVs customers and can consequently have greater requests for the

Table 7

Weights of the criteria and scores of all the sub-criteria for Baghdad.

Criteria	Weighted	Influences	Sub-criteria	Rank factor	Influence Level
Amenities	0.257	25.7	0–0.5 km	8	Very High Suitable
			0.5–1 km	6	High Suitable
			1–2 km	5	Moderate Suitable
			2–5 km	3	Low Suitable
			5–15 km	1	Very Low Suitable
Fuel/Gas Stations	0.136	13.6	0–1 km	8	Very High Suitable
			1–5 km	6	High Suitable
			5–10 km	5	Moderate Suitable
			10–30 km	3	Low Suitable
			30–50 km	1	Very Low Suitable
Road	0.134	13.4	0–0.5 km	7	Very High Suitable
			0.5–1 km	5	High Suitable
			1–2 km	4	Moderate Suitable
			2–5 km	3	Low Suitable
			5–10 km	1	Very Low Suitable
Parking Area	0.107	10.7	0–1 km	9	Very High Suitable
			1–5 km	7	High Suitable
			5–10 km	5	Moderate Suitable
			10–30 km	4	Low Suitable
			30–50 km	2	Very Low Suitable
Commercial Offices	0.076	7.6	0–2 km	8	Very High Suitable
			2–5 km	6	High Suitable
			5–10 km	5	Moderate Suitable
			10–20 km	3	Low Suitable
			20–50 km	1	Very Low Suitable
Railway/Metro	0.062	6.2	0–1 km	7	Very High Suitable
			1–5 km	5	High Suitable
			5–10 km	4	Moderate Suitable
			10–20 km	3	Low Suitable
			20–30 km	2	Very Low Suitable
Bus Dept	0.058	5.8	0–2 km	8	Very High Suitable
			2–5 km	6	High Suitable
			5–10 km	5	Moderate Suitable
			10–20 km	3	Low Suitable
			20–50 km	1	Very Low Suitable
Vegetation (NDVI)	0.05	5	−0.626 to −0.346	8	Very High Suitable

Table 7 (continued)

Criteria	Weighted	Influences	Sub-criteria	Rank factor	Influence Level
Water Body (NDWI)	0.046	4.6	−0.346 to −0.242	5	High Suitable
			−0.24 to −0.152	4	Moderate Suitable
			−0.153 to −0.021	2	Low Suitable
			−0.022 to 0.255	1	Very Low Suitable
			−0.331 to −0.248	5	High Suitable
			−0.249 to −0.165	3	Moderate Suitable
			−0.165 to −0.011	2	Low Suitable
			−0.012 to −0.331	1	Very Low Suitable
			0.029 to 0–0.5 km	8	Very High Suitable
			0.5–1 km	7	High Suitable
Built-up Area	0.029	2.9	1–2 km	5	Moderate Suitable
			2–5 km	3	Low Suitable
			5–20 km km	1	Very Low Suitable
			Carbon Monoxide (CO)	0.026	Very High Suitable
			Slope	0.02	Very High Suitable
Parking Area	0.107	10.7	Very High Suitable	8	Very High Suitable
			High	6	High Suitable
			Moderate	5	Moderate Suitable
			Less	4	Low Suitable
			Very Less	2	Very Low Suitable
Commercial Offices	0.076	7.6	Very Low Suitable	9	Very High Suitable
			1.218–2.456	7	High Suitable
			2.457–3.945	5	Moderate Suitable
			3.946–6.671	2	Low Suitable
			6.672–44.527	1	Very Low Suitable

charging substructure since these people were related through an additional pleasant situation and healthier air excellence ([Figs. 3 and 4](#)). Connection of the EVCSs popular zones with the higher rate of NDVI standards can principal to better ecological assistance, as it might encourage the adoption of detergent vehicles and decrease air pollution.

3.5.9. Water bodies (NDWI)

The water bodies' distance was an additional factor that can touch EVCSs suitability in Baghdad and Riyadh. The EVCSs situated near water areas might be less appropriate because of the possibility of EVs and water damage. The zones neighbouring water areas might remain disposed toward flooding throughout the monsoon period, which might injure the charging substructure with influence its obtainability aimed at the EV customers ([Figs. 3 and 4](#)). The Landsat 8 was practical to compute normalized Difference Water Index (NDWI) for approximating the water zone of both cities like Baghdad and Riyadh.

3.5.10. Built-up lands

The built-up lands are more essential to identifying the EVCS because those regions have more population and vehicle charging stations need

Table 8

Pairwise comparison matrix for multi-criteria decision analysis for Riyadh.

Criteria	Amenities	Fuel/Gas Station	Road	Parking Station	Commercial Offices	Railway/Metro	Bus Dept	Vegetation	Water Bodies	Built-up Area	Carbon Monoxide	Slope
Amenities	1	5	4	4	4	5	3	4	6	4	5	6
Fuel/Gas Stations	0.2	1	2	3	2	3	4	3	4	4	3	5
Road	0.25	0.5	1	4	3	3	2	4	4	4	4	5
Parking Station	0.25	0.333	0.25	1	3.5	2.5	3	3	3	3.5	4.5	4
Commercial Offices	0.25	0.5	0.333	0.286	1	2	2	2	2	3	3.5	4
Railway/Metro	0.2	0.333	0.333	0.4	0.5	1	1	2	2	3	3	3.5
Bus Dept	0.333	0.25	0.5	0.333	0.5	1	1	2	2	2.5	3	3
Vegetation	0.25	0.333	0.25	0.333	0.5	0.5	0.5	1	3	2.5	2	4
Water Bodies	0.167	0.25	0.25	0.333	0.5	0.5	0.5	0.333	1	4.5	3	2
Built-up Area	0.25	0.25	0.25	0.286	0.333	0.333	0.4	0.4	0.222	1	1	3
Carbon Monoxide	0.2	0.333	0.25	0.222	0.286	0.333	0.333	0.5	0.333	1	1	2
Slope	0.167	0.2	0.2	0.25	0.25	0.286	0.333	0.25	0.5	0.333	0.5	1
Total	3.517	9.283	9.617	14.444	16.369	19.452	18.067	22.483	28.056	33.333	33.5	42.5

Table 9

Standardized matrix and weighted distribution for multi-criteria decision analysis for Riyadh.

Criteria	Amenities	Fuel/Gas Station	Road	Parking Station	Commercial Offices	Railway/Metro	Bus Dept	Vegetation	Water Bodies	Built-up Area	Carbon Monoxide	Slope	Weight
Amenities	0.284	0.539	0.416	0.277	0.244	0.257	0.166	0.178	0.214	0.120	0.149	0.141	0.249
Fuel/Gas Stations	0.057	0.108	0.208	0.208	0.122	0.154	0.221	0.133	0.143	0.120	0.090	0.118	0.140
Road	0.071	0.054	0.104	0.277	0.183	0.154	0.111	0.178	0.143	0.120	0.119	0.118	0.136
Parking Station	0.071	0.036	0.026	0.069	0.214	0.129	0.166	0.133	0.107	0.105	0.134	0.094	0.107
Commercial Offices	0.071	0.054	0.035	0.020	0.061	0.103	0.111	0.089	0.071	0.090	0.104	0.094	0.075
Railway/Metro	0.057	0.036	0.035	0.028	0.031	0.051	0.055	0.089	0.071	0.090	0.090	0.082	0.060
Bus Dept	0.095	0.027	0.052	0.023	0.031	0.051	0.055	0.089	0.071	0.075	0.090	0.071	0.061
Vegetation	0.071	0.036	0.026	0.023	0.031	0.026	0.028	0.044	0.107	0.075	0.060	0.094	0.052
Water Bodies	0.047	0.027	0.026	0.023	0.031	0.026	0.028	0.015	0.036	0.135	0.090	0.047	0.044
Built-up Area	0.071	0.027	0.026	0.020	0.020	0.017	0.022	0.018	0.008	0.030	0.030	0.071	0.030
Carbon Monoxide	0.057	0.036	0.026	0.015	0.017	0.017	0.018	0.022	0.012	0.030	0.030	0.047	0.027
Slope	0.047	0.022	0.021	0.017	0.015	0.015	0.018	0.011	0.018	0.010	0.015	0.024	0.019
	1	1	1	1	1	1	1	1	1	1	1	1	1

for vehicle charging. Therefore, built-up areas are essential to identify the EVCS. Many areas of the built-up lands are near sub-street areas; therefore, investigators need to identify the suitable areas of built-up lands. Mostly residential locations are more suitable like near to apartments, buildings, and colony locations (Figs. 3 and 4). The built-up lands or residential areas are calculated through satellite-based image classification techniques (Landsat 8 OLI/TIRS data) while both major cities have under 0.5 km of very high suitable zones for EVCS establishment.

3.5.11. Carbon monoxide (CO)

AQI is a significant influence on the deliberate place appropriateness examination for the EVCSs, as air contaminants can disturb the health with happiness of the person's popular nearby zone. In wide-ranging, places with high levels of pollution of air would be favored aimed at the position of EVCSs. This was because EVs harvest no emissions at the tailpipe, consequently, placement EVCSs in portions within height of the pollution would be real hip-dropping general emissions (Figs. 3 and 4). Consequently, when leading location appropriateness analysis for the EVCS, it is significant to take obsessed by explaining the resident quality of air circumstances and also guidelines to guarantee that EVs charging positions were situated in zones that were actually popular dropping emissions.

3.5.12. Slope

The slopes of places can touch the position assortment procedure of the EVCSs in terms of both building feasibility and cost. The analytical part comprises areas that have a high slope and are nonstable. For these details, the slope map coating was shaped by executing the slope spatial analysis toolbox of the software named ArcMap. the SRTM DEM that was bigheartedly dispersed with the world was applied as a foundation dataset. If a site has a little slope, its determination be additional appropriate.

4. Results and discussion

Renewables are superlative alternatives to fossil fuels that were progressively discovered their residence in the energy subdivision of each nation with each civilization. Cumulative pollution since the fossil fuels, the greatest connected to the transport subdivision, is the foremost chauffeur for replacement renewable capital in the selected sector. Numerous schemes with investigations, renewable energy applications like solar, geothermal, or hydro resources to produce electricity, and energy procedures aimed at space, home-based lighting, with water heating aimed at the numerous applications and EVCSs have been measured. Replacement of EVs with fossil fuel-related vehicles on one needle, increasing clean energy applications like produce electricity

Table 10
Estimation of the consistency ratio for Riyadh.

Criteria	Amenities	Fuel/Gas Station	Road	Parking Station	Commercial Offices	Railway/Metro	Bus Dept	Vegetation	Water Bodies	Built-up Area	Carbon Monoxide	Slope	Total	Cr
Amenities	0.249	0.701	0.544	0.428	0.301	0.298	0.182	0.207	0.265	0.120	0.137	0.116	3.547	14.256
Fuel/Gas Stations	0.050	0.140	0.272	0.321	0.150	0.179	0.243	0.155	0.176	0.120	0.082	0.097	1.986	14.172
Road	0.062	0.070	0.136	0.428	0.226	0.179	0.122	0.207	0.176	0.120	0.109	0.097	1.932	14.208
Parking Station	0.062	0.047	0.034	0.107	0.263	0.149	0.182	0.155	0.132	0.105	0.123	0.078	1.437	13.430
Commercial Offices	0.062	0.070	0.045	0.031	0.075	0.119	0.122	0.103	0.088	0.090	0.096	0.078	0.979	13.011
Railway/Metro	0.050	0.047	0.045	0.043	0.038	0.060	0.061	0.103	0.088	0.090	0.082	0.068	0.774	12.998
Bus Dept	0.083	0.035	0.068	0.036	0.038	0.060	0.061	0.103	0.088	0.075	0.082	0.058	0.786	12.936
Vegetation	0.062	0.047	0.034	0.036	0.038	0.030	0.030	0.052	0.132	0.075	0.055	0.078	0.668	12.917
Water Bodies	0.041	0.035	0.034	0.036	0.038	0.030	0.030	0.017	0.044	0.135	0.082	0.039	0.561	12.716
Built-up Area	0.062	0.035	0.034	0.031	0.025	0.020	0.024	0.021	0.010	0.030	0.027	0.058	0.377	12.583
Carbon Monoxide	0.050	0.047	0.034	0.024	0.021	0.020	0.026	0.015	0.030	0.027	0.039	0.353	12.888	
Slope	0.041	0.028	0.027	0.027	0.019	0.017	0.020	0.013	0.022	0.010	0.014	0.019	0.258	13.274
													159.391	

Maximum Eigenvalue (λ_{max}) = 13.28254478.

$$n = 12.$$

$$\text{Consistency index (CI)} = \frac{(\lambda_{max} - n)}{(n - 1)} = 0.11659498.$$

Random index (RI) = 1.54.

$$\text{Consistency ratio (CR)} = \left(\frac{CI}{RI} \right) = 0.078780392.$$

Table 11
Weights of the criteria and scores of all the sub-criteria for Riyadh.

Criteria	Weighted	Influences	Sub-criteria	Rank factor	Influence Level
Amenities	0.249	24.9	0–0.5 km	8	Very High Suitable
			0.5–2 km	7	High Suitable
			2–5 km	5	Moderate Suitable
			5–10 km	3	Low Suitable
			10–50 km	1	Very Low Suitable
Fuel/Gas Stations	0.140	14.0	0–1 km	8	Very High Suitable
			1–5 km	7	High Suitable
			5–10 km	5	Moderate Suitable
			10–30 km	2	Low Suitable
			30–50 km	1	Very Low Suitable
Road	0.136	13.6	0–0.5 km	8	Very High Suitable
			0.5–1 km	6	High Suitable
			1–2 km	4	Moderate Suitable
			2–5 km	3	Low Suitable
			5–12 km	1	Very Low Suitable
Parking Area	0.107	10.7	0–1 km	8	Very High Suitable
			1–3 km	6	High Suitable
			3–8 km	4	Moderate Suitable
			8–15 km	3	Low Suitable
			15–50 km	1	Very Low Suitable
Commercial Offices	0.075	7.5	0–1 km	9	Very High Suitable
			1–3 km	7	High Suitable
			3–10 km	6	Moderate Suitable
			10–30 km	3	Low Suitable
			30–70 km	1	Very Low Suitable
Railway/Metro	0.060	6.0	0–1 km	8	Very High Suitable
			1–3 km	6	High Suitable
			3–7 km	4	Moderate Suitable
			7–15 km	3	Low Suitable
			15–80 km	1	Very Low Suitable
Bus Dept	0.061	6.1	0–1 km	7	Very High Suitable
			1–5 km	5	High Suitable
			5–10 km	3	Moderate Suitable
			10–30 km	2	Low Suitable
			30–70 km	1	Very Low Suitable
Vegetation (NDVI)	0.052	5.2	-0.271 to 0.081	8	Very High Suitable

(continued on next page)

Table 11 (continued)

Criteria	Weighted	Influences	Sub-criteria	Rank factor	Influence Level
Water Body (NDWI)	0.044	4.4	0.080–0.112	6	High Suitable
			0.113–0.173	4	Moderate Suitable
			0.174–0.295	3	Low Suitable
			0.296–0.594	1	Very Low Suitable
			-0.558 -	8	Very High Suitable
			-0.294		
			-0.295 -	6	High Suitable
			-0.238		
			-0.39 -	4	Moderate Suitable
			-0.193		
Built-up Area	0.030	3.0	-0.194 -	3	Low Suitable
			-0.138		
			-0.139 -	1	Very Low Suitable
			-0.389		
			0–0.5 km	8	Very High Suitable
Carbon Monoxide (CO)	0.027	2.7	0.5–1 km	6	High Suitable
			1–2 km	4	Moderate Suitable
			2–5 km	3	Low Suitable
			5–20 km	1	Very Low Suitable
			Very High Suitable		
Slope	0.019	1.9	High	5	High Suitable
			Moderate	3	Moderate Suitable
			Less	2	Low Suitable
			Very Less	1	Very Low Suitable
			Very High Suitable		

from solar energy, and applying this technique to charge vehicles have been beautiful themes in the government strategy, particularly in the European republics.

4.1. Suitability sites of Baghdad city

The major city in Iraq, Baghdad is also a capital city, which is more important not only in recent times but also in past eras. Every year environmental degradation and air pollution gradually increase in this capital city. Fossil fuel is limited even in production countries, therefore electric vehicle use is gradually increasing throughout the world. Many charging stations are already established in Iraq like Mansour (2 stations) while Karadah, Al-Midaina, and Ramadi have one individually. Furthermore, some regions need proper justification to identify the appropriate location of EVCSs in Baghdad. Therefore, some selected criteria are applied for EVCS identification in Baghdad. Both two different types of methods AHP, and FAHP have five different suitability levels (Fig. 5). For AHP methods very high suitable (179.99 km^2), high suitable (686.23 km^2), moderate suitable (1410.72 km^2), low suitable (2267.59 km^2), and very low suitable (552.47 km^2) respectively (Table 12). Karkh,

Dora, Hurriya, Yarmouk, Binouk, and near the Baghdad International Airport are more suitable for EVCSs to establish. For the FAHP method, very high suitable (3.19 %), high suitable (14.57 %), moderate suitable (16.55 %), low suitable (34.36 %), and very low suitable (31.33 %) respectively. Those regions are more appropriate for EVCS identification and some other criteria like land values and land availability play a vital role in identifying the EVCS in Baghdad city. This analysis uses real-time datasets from the EVCSs to compute power demands of respectively EVCS, which were then joined with made power of the PVNBs to attain a competition amid power demand of the EVCS and PVNB power supply at the entire city scale. Then, PVNB electricity is efficiently used, and dependence on the EVCSs on chief power network is minimalized (Zhang et al., 2024). In the setting of the transitioning from the conventional to the E-Transportation, carbon emissions production is a vital part in the decisive feasibility and aids of like a shift. The control of Total Carbon Redeemable, an essential formulation, receipts centre stage in this endeavour. This formulation reflects the solar photovoltaic systems impact and their interaction with grid, factorization in the carbon emission investments resulting from utilization of the solar power (Gupta et al., 2023).

To control appropriate sites for EVCSs, the GIS-based MCDM method was applied by using a model that was clarified in the methodology unit. In this classic, though altogether spatial examination procedures can be understood as the yellow color, altogether production datasets can be seen as green (Guler & Yomralioğlu, 2020). The continuing encounter of a lack of nearby EVCSs was predominantly plain for groups with smaller profits with areas with a better fraction of multiple-units houses. The community EVCSs were vital for the EVs process in those parts because of the fewer probable admissions to the confidentially possessed inhabited chargers. The two different greatest significant criteria rendering the importance of sub-criterions were coldness to the roads with proximity to the profitable workplaces. A crucial feature of the analysis includes familiarizing and applying criteria with GIS. The dependability and precision datasets foundations and criteria straight affect suitability map accuracy (Rane et al., 2023). The aim was to detect whether optimal other variations when AHP weights were amplified or condensed through 10 % to 100 %. The outcomes presented those controls altered as the ratio enlarged or decreased. When criteria weights growth or decrease to subsequent magnitudes, optimal alternate variations (Dang et al., 2021). The EVs production an important character in dipping energy feasting and environmental pollution. Consequently, examining the EVCSs place was actually expressive of sustainable cities and society. Indorsing application of EVs in great cities was actually for refining environmental pollution and dropping carbon emissions. For example, growing populated cities like Chengdu (China) need to accept green economic rules to remediate environmental difficulties energetically (Feng et al., 2021).

4.2. Suitability sites of Riyadh city

Riyadh, the capital city of Saudi Arabia has some electric charging stations because those regions have already established some EVCSs in the city area. Due to the high number of vehicles used some regions are gradually polluted therefore green energy is essential to establish a healthy environment in the city area. For AHP methods very high suitable (0.51 %), high suitable (11.38 %), moderate suitable (31.52 %), low suitable (50.61 %), and very low suitable (5.97 %) separately (Fig. 6). In Riyadh Dhahrat Laban, Ash Shifa, Al-Sina'yah, Tuwaiq, Al-Olaya, and Al-Murabba are more Suitable for EVCSs. While for the FAHP method, very high suitable (34.27 km^2), high suitable (962.34 km^2), moderate suitable (2922.94 km^2), low suitable (4307.86 km^2), and very low suitable (463.59 km^2) correspondingly (Fig. 7). The land values, public demands, and vehicle costs are improving the suitability level of this region. Planners, administrators, and other stakeholders can also observe before establishing the EVCS in Riyadh City. Those results can help to build green energy-related infrastructure and improve the local

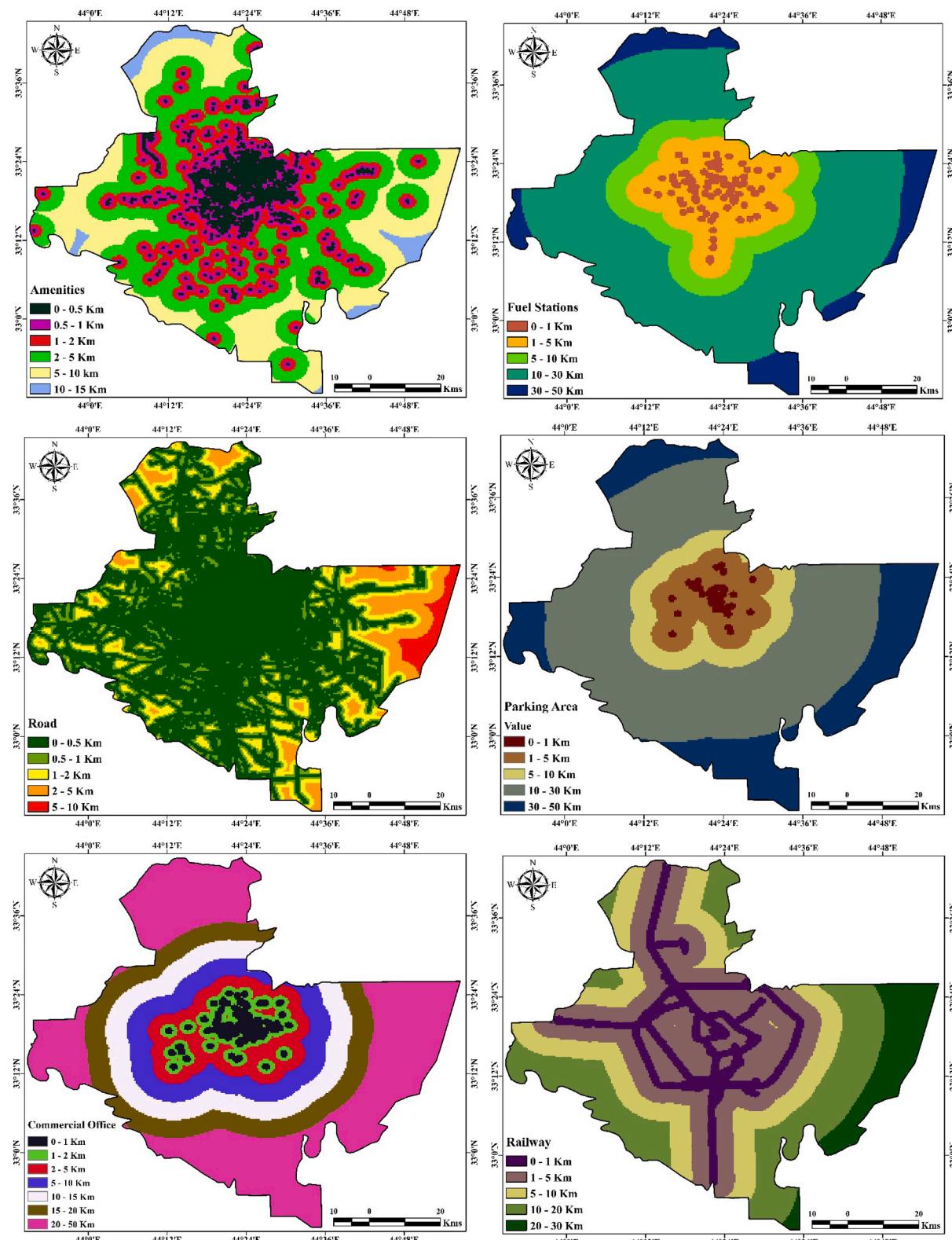


Fig. 3. Criteria map for Baghdad EVCs analysis.

air quality, environment, and human health. The use of fossil fuel reduction can help to see our future generation; and how fossil fuel also apply for vehicles and another purpose. The results of EVCSS in Baghdad and Riyadh have improved the planning and management toward

sustainable development with green energy in those regions. This method can be applied with and without modification in different parts of the globe. Globally charging tendencies propose that the charging at the homebased books for around 50–80 % of the EVs charging wants.

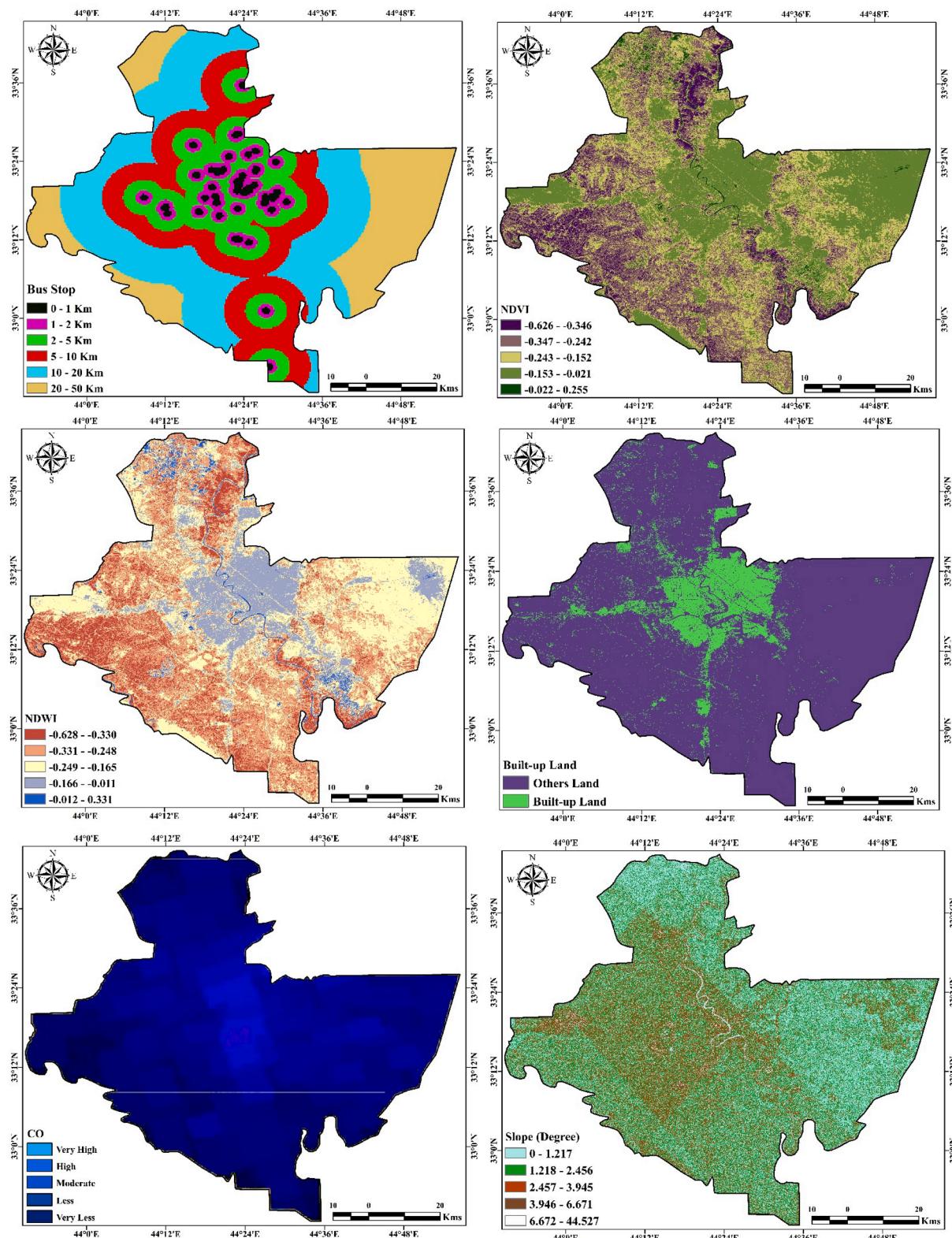


Fig. 3. (continued).

Numerous cross-national educations likewise disclose that the most EVs charge at the homebased, shadowed by workplace and also in the public infrastructure. Though, supplementing E-CP substructure leftovers a credible plan as it is debatable that proportion of the homebased charging was based on the household delivery at different districts (Sikder et al., 2023).

Istanbul, where analysis shown, was maximum populous urban in Turkey which it forms the economy of the country. Subsequently urban reproduces Turkey by way of an entire, Istanbul is designated as an analysis zone. Seeing both complete cities and distinct regions provides an extra viewpoint. The assessment of the current and other EVCSSs is complete with the GIS-based of the MCDM with other numbers of the

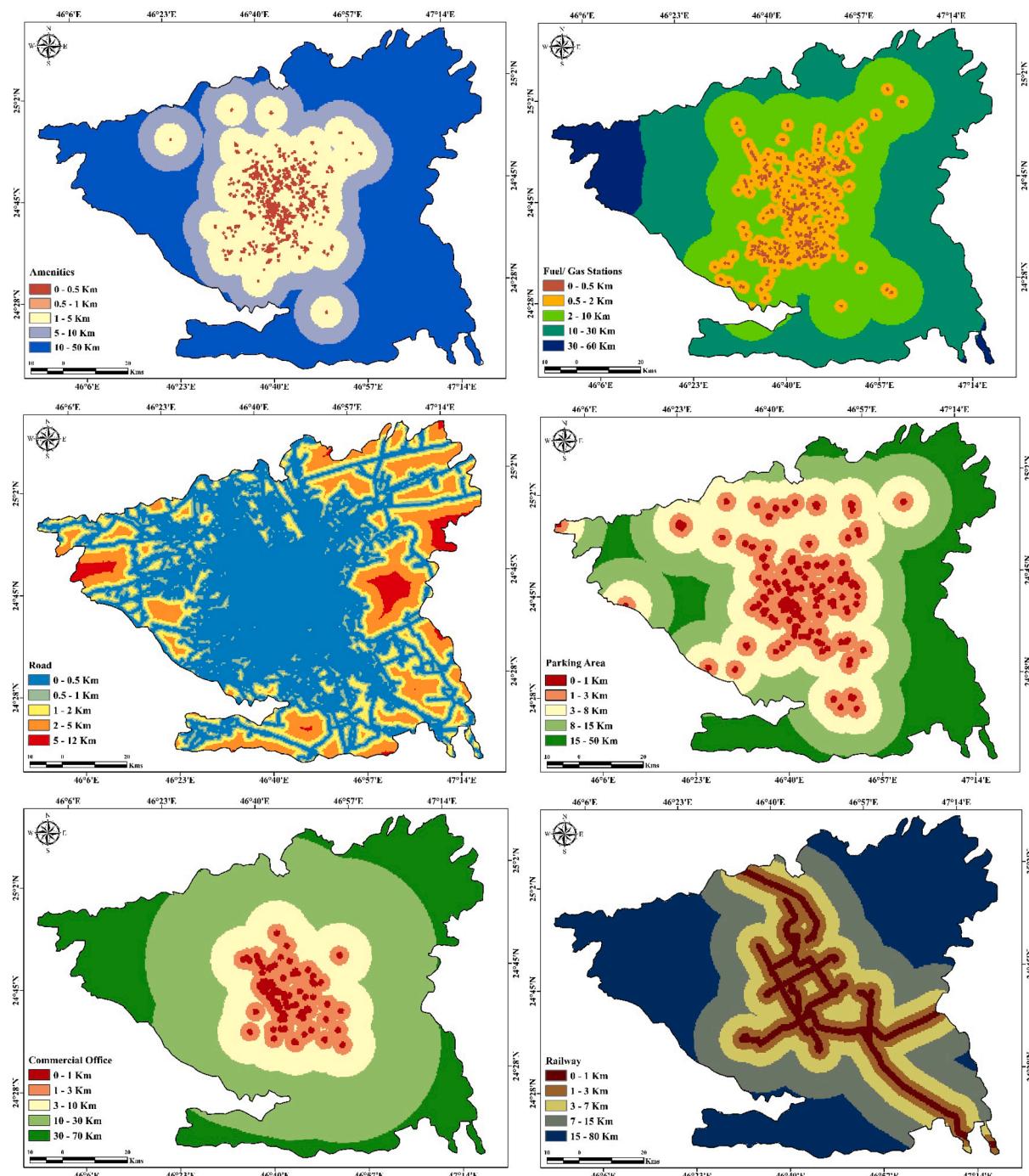


Fig. 4. Criteria map for Riyadh EVCs analysis.

EVCSS resulting in the parallel with the amount of the present EVCSSs. The PROMETHEE, AHP, and also VIKOR are applied composed with the GIS aimed at the first period to control EVCSS sites (Kaya et al., 2020). Throughout decision procedure, this was problematically aimed at specialists to deliver crunchy standards for the evaluation criteria because of information uncertainty and human recognition vagueness. Consequently, it is significant for local administrations to find fitting techniques to assess with choice of the EVCS place. In this analysis, researchers suggest a new outline combination with the FAHP method and the GRP technique to resolve EVCS site assessment and assortment difficulties below the image fuzzy atmosphere (Ju et al., 2019). The spatial examines of the criteria were achieved with the GIS and also the ETCS

appropriateness diagram was obtained. In the appropriateness map, the European southeast part side and the Anatolian southwestern part side were strongminded as greatest suitable zone for the ETCS. The ETCS number to be allocated was strongminded as around 180 considering the capacity of EVCSSs and taxis number. The EVs number that can be helped through EVCSSs was modeled applying three-sided delivery with limits like 325, 355, and 384) because of the uncertainty complicated with the estimate of the position's facility close. It was valuable to understand how selection likelihood of the first other variations when a facility equal to the primary another place was secure to around 330 EVs (Hosseini & Sarder, 2019).

Numerous standards necessities be occupied hooked on explanation

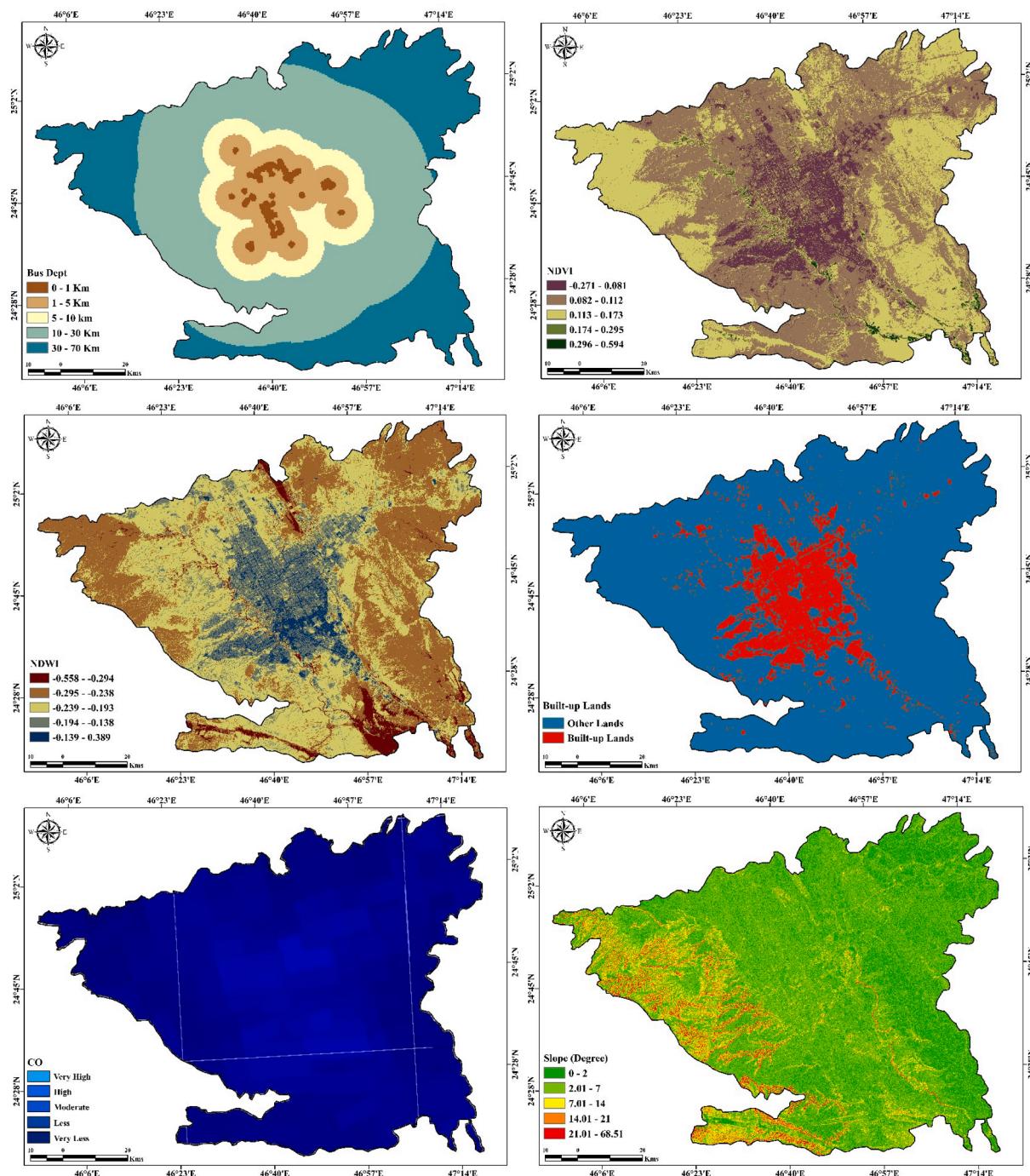


Fig. 4. (continued).

in the appropriate placement of the EVCSSs. This condition demonstrates that these difficulties must be resolved with the multiple-criteria method. Furthermore, the reliability and quality of criteria datasets were significant for a precise siting procedure. The procedure similarly necessitates spatial dataset analysis. Consequently, it is appropriate to combine techniques to apply GIS-based of the GIS-based multi-criteria decision-making (MCDM) technique aimed at EVCSSs place assortment. The GIS is a discipline that covers altogether of the spatial information schemes and inspects geographic material. The GIS achieves purposes like storing, collecting, presenting, analysing, and modeling gotten material in honesty with the location-based comments. These topographies were a foremost factor that differentiates GIS from additional

schemes. Examination purposes of the GIS apply relative of objects in the database (Rane et al., 2023). The EVs have conventional countless deal of courtesies as for interior combustion engine vehicles (ICEV) because of their economic environmental significance and affordability. Both the administration and the Tehran Municipality where secondary continuing investigates numerous features of the EVs request to deliver the thoughtful vision for the policymaking on electro-mobility. The sustainability in the energy organization scope aims to meet wants of the current deprived of conciliatory upcoming compeers' ability to encounter their energy pressures (Charly et al., 2023). This might be produced through emerging renewable foundations, creating more efficient technologies and cleaners, and lastly using additional

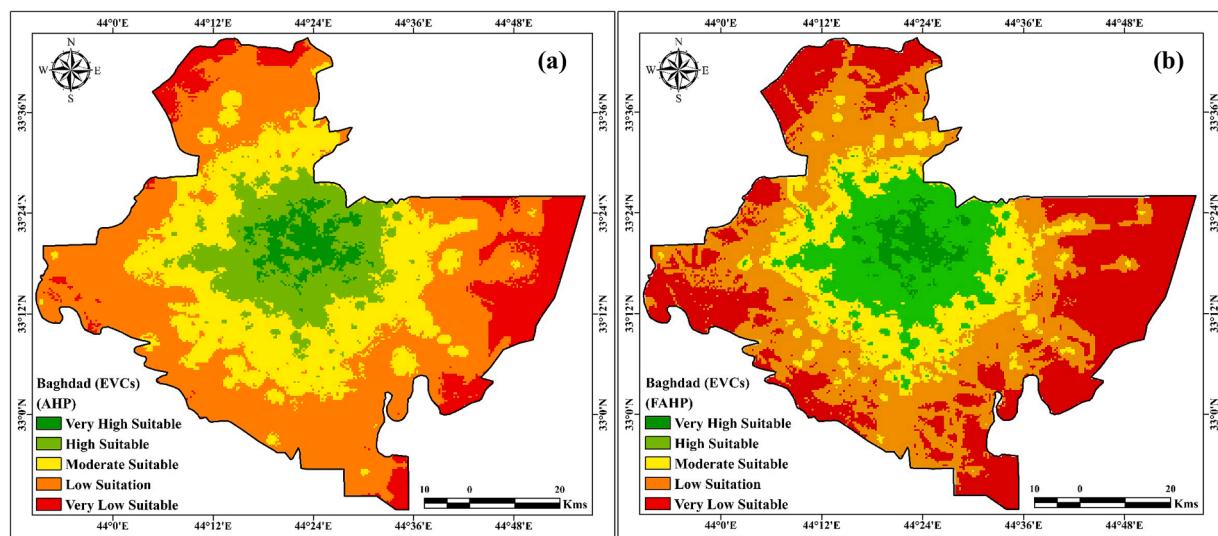


Fig. 5. Suitability mapping of Baghdad EVCs using AHP and Fuzzy-AHP.

Table 12
Area of the EVCs suitability of Baghdad and Riyadh.

Suitability	Baghdad			
	Method			
	AHP (km^2)	AHP (%)	FAHP (km^2)	FAHP (%)
Very High Suitable	179.99	3.53	162.61	3.19
High Suitable	686.23	13.46	742.56	14.57
Moderate Suitable	1410.72	27.68	843.73	16.55
Low Suitable	2267.59	44.49	1751.36	34.36
Very Low Suitable	552.47	10.84	1596.74	31.33

Suitability	Riyadh			
	Method			
	AHP (km^2)	AHP (%)	FAHP (km^2)	FAHP (%)
Very High Suitable	44.51	0.51	34.27	0.04
High Suitable	989.47	11.38	962.34	11.07
Moderate Suitable	2739.83	31.52	2922.94	33.63
Low Suitable	4398.76	50.61	4307.86	49.57
Very Low Suitable	518.43	5.97	463.59	5.33

professionals and with better preservation. Sustainability in the setting of the renewable energy organization contains around three magnitudes: social, and economic expansion, with also in ecological protection.

5. Limitations and future research direction

To allow extensive acceptance of the EVs, it was vital to speech encounters of incomplete range and insufficient substructure for the EVCSs. Developing republics like India have previously started transition to the EVs, but decisive suitable, and effectual sites for the EVCSs in these nations necessitate further examination. Decisive optimal places for building the EVCS were crucial to guaranteeing high-quality facilities and working efficiency. The chief difficulty of analysis in the literature which applied the MCDM methods was the inadequacy of addition between spatial datasets and assessment standards. The spatial decision difficulties stretch increase to GIS-based the MCDM examination. Consequently, two illustrious distinguishing of this analysis, the GIS and the MCDM can advantage to resolve difficulties of the spatial datasets and policymaking examination. On the other side, answer methods of the GIS method can yield explanations for decision-making difficulties in addition to the examination of spatial datasets. Certainly, the GIS was frequently documented ‘as a decision support system connecting

addition of spatially referenced datasets in the problem-solving environment’. To improve outcomes assessed from the geospatial analysis, numerous extra criteria can be combined, like on-street vehicle parking designs, distance from the power grid outlines, and household amount applying the EVs. Developments in documentation of the EVCSs sites can be attained by taking into account the influence of pricing on request variations and user accusing behaviour. Additionally, additional investigation was essential to find speculation urgencies for the terminus and the route charging, with renewable energy based on the EVCSs.

6. Conclusion

Renewables energy is the best substitute for fossil fuels, and they progressively discovered their residence in the energy subdivision of each nation with each civilization. Growing contamination since the fossil fuels, a maximum of those were connected to the transport segment, has been the foremost driver for replacement renewable capital in this subdivision. In numerous schemes and analyses, renewable energy applies like solar, geothermal, or hydro capitals to produce power and the usage of the energy form aimed at home-based space, and lighting, with water heating aimed at the numerous usages and the charging EVs were measured. Replacement EVs with fossil fuel buses on the one hand, increasing the use of clean energy like solar energy used to produce electricity, with applying the technique to charge vehicles have been beautiful matters in administration strategy, particularly around European nations.

- Baghdad and Riyadh are major cities where fossil fuel-based vehicles increase air pollution and impact human health, therefore electric vehicles may be an alternative for vehicle use and reduce air pollution in the entire city. Sustainable development and healthy environment can improve human health conditions and reduce fossil fuels used gives us a chance for future generations to see fossil fuels.
- Based on the EVCSs investigation, very high suitable zones of Baghdad city have 179.99 km^2 (AHP), and 162.61 km^2 (FAHP), while Riyadh has 44.51 km^2 (AHP), and 34.27 km^2 (FAHP) respectively. Those areas are calculated based on the twelve criteria while some effective criteria are important in the city locations like land values, existing EVCSs, Lithium battery production areas, and many more. This helps more accurate zone identification of EVCSs.
- The planned scientific procedure can be effortlessly modified for the different metropolises through the creation of essential alterations. This analysis delivers a scientific framework for analyzing, assessing, and classifying appropriate sites for the EVCSs, thus causative to

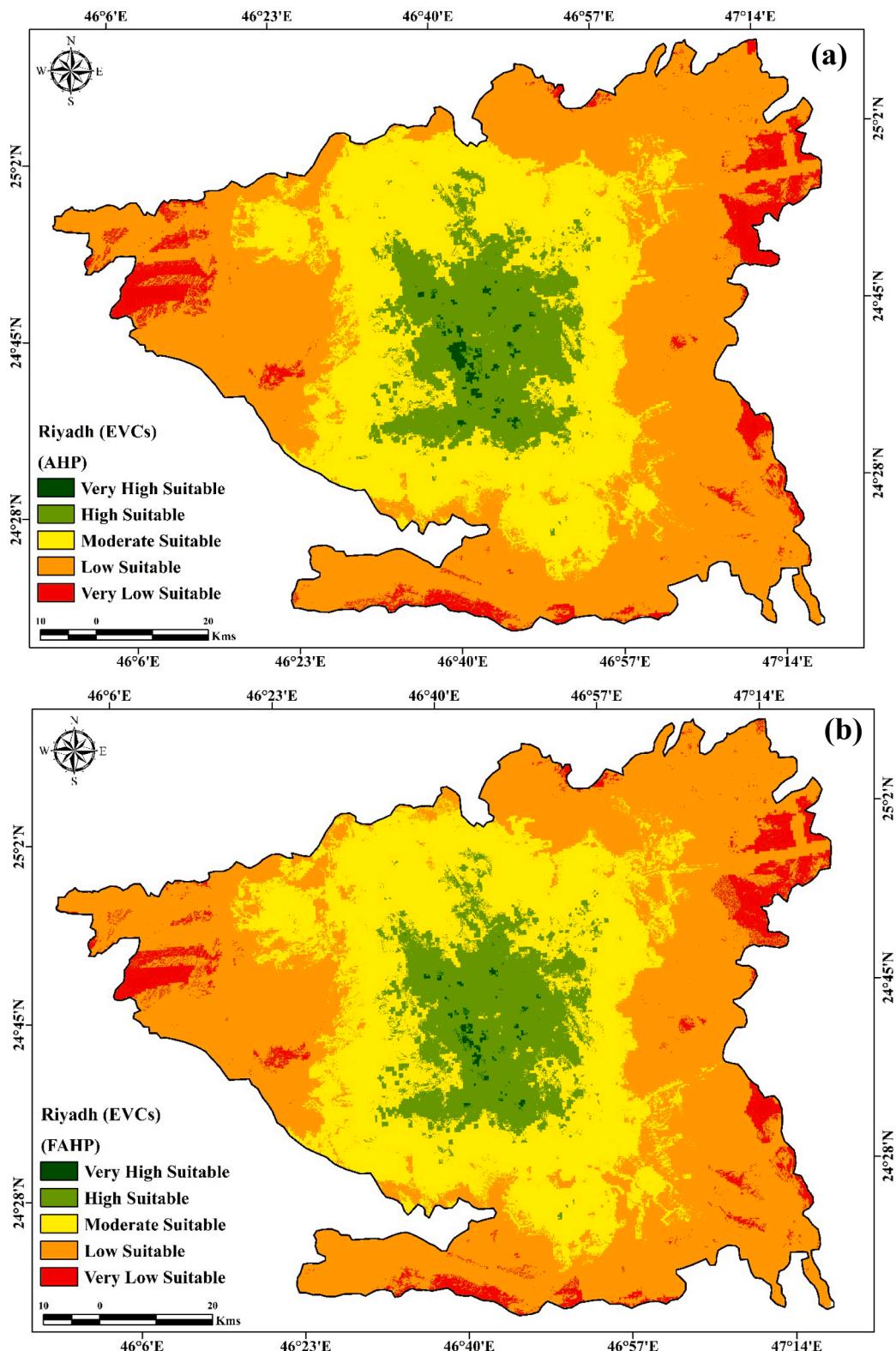


Fig. 6. Suitability mapping of Riyadh EVCs using AHP and Fuzzy-AHP.

sustainable transportation and also in energy. This signifies an important pace near more accountable and effectual decision-making. Limits of work propose in the MCDM method, resolution of imagery, with also dataset accessibility.

CRediT authorship contribution statement

Khalid Hardan Mhana: Methodology, Investigation, Formal analysis, Data curation, Conceptualization, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing –

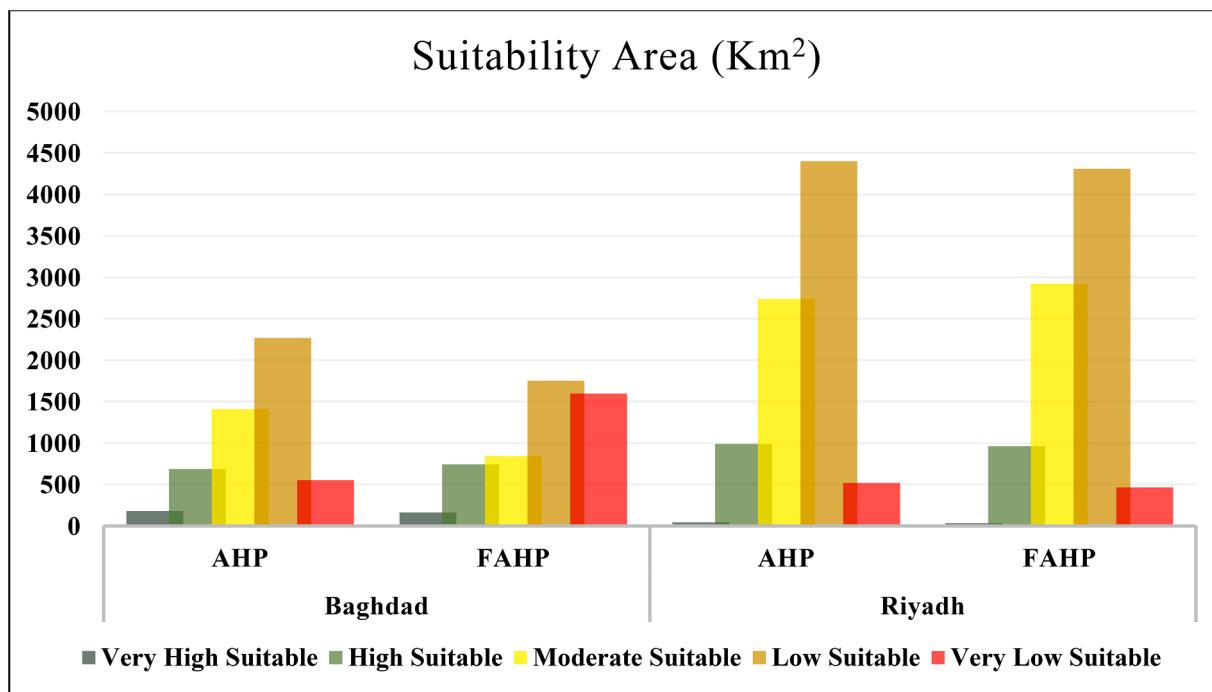


Fig. 7. Suitability level of two applied methods in Baghdad and Riyadh.

original draft, Writing – review & editing. **Hamid Ahmed Awad:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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