



A Geospatial Multi-Criteria Framework for High-Rise Development Site Selection in Dense Urban Areas: Evidence from Karrada District, Baghdad

Khulood A. Al-Salim¹ , Ahmed A. Al-Jaberi^{2*} , Amal Mansoor Hasan³ , Suhad K. Al-Mosawy² 

¹ Department of Business Administration, College of Administration and Economics, Uruk University, Baghdad 10071, Iraq

² Faculty of Physical Planning, University of Kufa, Kufa 54001, Iraq

³ Department of Business Administration, Al-Nisour University, Baghdad 10071, Iraq

Corresponding Author Email: ahmeda.hanash@uokufa.edu.iq

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ABSTRACT

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There are huge challenges in accommodating urban growth within dense cities, particularly given the limited availability of developable land. This makes high-rise buildings an effective option, and the selection of their locations is a complex planning decision that requires balancing environmental, social, economic, and physical considerations. Therefore, this paper aimed to develop and apply a geospatial suitability assessment framework for evaluating the spatial suitability of high-rise buildings within Karrada District by integrating Geographic Information Systems (GIS), Multi-Criteria Analysis, and Analytical Hierarchy Process (AHP). Seven criteria were grouped under four factors (environmental, social, economic, and physical) to assess the relative spatial suitability for high-rise development within the high-density urban context of Karrada District. The weights of the criteria were determined based on pairwise comparisons conducted by seven experts, and the group comparison matrix showed a high level of consistency, with a consistency ratio of 0.0033. The spatial layers were then reclassified to a uniform scale and merged using the weighted overlay method. Results indicated that Proximity to undeveloped and buildable land was given the maximum weight of 20%, whereas Distance from high-value land was given the weight of 16%. The very high suitability class was concentrated in areas within Rashid Camp in Jamea quarter (neighborhood 917) and Babylon quarter (neighborhood 927). The total area which was classified as high/very high spatial suitability was about 2,213.39 hectares, constituting only about 29.69% of the study area. Independent expert validation further supported the planning and spatial plausibility of the model outputs, with an overall mean score of 4.28 out of 5. The results provide a tool for strategic spatial screening and for guiding detailed studies, but they do not represent direct approval of development before verifying land ownership, infrastructure capacity, and regulatory, geotechnical, and traffic constraints.

1. INTRODUCTION

Rapid population growth and the scarcity of development land have posed a fundamental challenge to the sustainable planning of large cities, particularly in dense urban areas in developing countries [1, 2]. For the purposes of this study, a high-rise building is defined as a building with a height of 50 m or more, consistent with the threshold commonly adopted in tall-building literature [3]. In the Iraqi context, rapid urban growth in Baghdad has been associated with increasing housing demand, unplanned expansion, traffic congestion, pressure on urban services, and spatial concentration of development, highlighting the need for planning approaches capable of accommodating growth while reducing pressure on the existing urban fabric [4]. In light of limited urban land and the desire to find the best use of it, high-rise development is a viable solution to accommodate population growth [5, 6]. Today, these structures are no longer only architectural landmarks, but are increasingly playing a key role in the

restructuring of an urban area that is increasingly forced to satisfy the housing, employment, and service needs of urban residents, and enhance the quality of their connection with urban services [7]. In the hot-arid context of Baghdad, previous research has shown that urban form, particularly building height, floor area ratio, building density, and the resulting shading conditions, can significantly influence outdoor air temperature, indicating that the vertical dimension of urban development has important microclimatic implications [8]. The process of selecting suitable sites remains complex due to the multiplicity of spatially interacting factors within urban systems, such as economic and social processes, transportation routes, infrastructure, and connectivity to the urban fabric of the parent city [9, 10]. In the Iraqi urban context, previous research has also shown that density, accessibility, social interaction, and the distribution of activities are important dimensions influencing the performance and vitality of urban spaces [11]. Other evidence from cities in Iraq also shows that accessibility, spatial

resilience, and social interactions are relevant planning and evaluation criteria for urban spaces, especially when evaluating the impact of (spatial) interventions in the distribution of urban opportunities and benefits [12].

In dense areas, high-rise buildings are effective in land use planning. On the one hand, they represent an effective solution to the problem of land scarcity, as they allow for accommodating larger populations and economic activities within a relatively small geographic area, thus contributing to the preservation of open land and green spaces outside the core urban area. Concentrating activities in high-density centers also increases the efficiency of public transportation networks and infrastructure and reduces reliance on private vehicles. Studying the factors affecting the planning of these structures within the framework of achieving spatial sustainability represents a clear challenge [13]. The introduction of a high-rise building into an existing urban fabric can impact traffic flows, local environmental conditions (such as shade and wind flow), and the capacity of water, sewage, and energy networks to accommodate additional loads [14]. However, these detailed factors often operate at the site or plot level, and therefore should be distinguished from the strategic spatial screening criteria used to identify primary priority areas.

Therefore, the decision to select the optimal location for such projects is not simply a matter of filling an urban void or remodeling existing buildings. Rather, it is a vital strategic decision that requires in-depth study and integration of various social, economic, urban, and environmental factors [15].

Hence, the search for and development of spatial analysis tools to understand urban processes and the interactions involved in the site selection of high-rise buildings has emerged [16].

Although previous literature has presented various models linking spatial analysis and multi-criteria decision-making methods for evaluating high-rise building sites, their application remains highly dependent on the nature of the urban context, data availability, and local planning constraints. Furthermore, their application is limited in the context of densely populated Iraqi cities, where land use patterns and values, population densities, transportation characteristics, and availability of developable land differ from the contexts in which most previous models were tested. Therefore, the research need lies in adapting these approaches to local characteristics and transforming available planning considerations into evaluable and comparable spatial criteria.

Paszkowski et al. [17] investigated the role of tall buildings in achieving sustainable urban development, taking the Hansa Tower in Szczecin (Poland) as a case study. The issue is how to evaluate the interaction of such modern constructions with the current urban fabric and the effects that they have on post-industrial spaces. The purpose of the study is to analyze and evaluate the impact of the tower from a functional, spatial, and social point of view. A qualitative methodology based on spatial and architectural analysis was adopted, focusing on social, functional/technical, and aesthetic/formative aspects. The results indicate that the tower represents an important element in the modern urban fabric, contributes to the revitalization of the area, and has great potential for achieving sustainable development.

In this context, Utami et al. [18] noted that the Indonesian city of Medan lacks a three-dimensional map of the distribution of high-rise buildings, and there is an urgent need for urban spatial planning maps for these buildings. The research aims to create a map of the distribution of high-rise

buildings in the West Medan sub-district and assess their compatibility with the service center areas in Medan. The methodology used a model integrated into ArcGIS, with high-resolution imagery data from SAS Planet and GPS coordinate data for high-rise buildings with more than four floors. The results showed that the distribution of high-rise buildings conforms to a relatively sparse and dense pattern in the West Medan sub-district, which is a center for commercial/business services, government services, and the economy.

Regarding environmental impacts, Weng and Zhuang [19] pointed to the problem of high-rise development in New York City and the impact of air rights policies on this development. The aim is to reveal the relationship between air rights policies and the evolution of high-rise urban block patterns, providing a reference for future policymakers. The methodology relies on extensive spatial analysis using Geographic Information Systems (GIS) to link building locations and apply air rights policies, as well as using Space matrix criteria to analyze urban density through zoning. The most critical results show that air rights methods (zoning lot mergers, transfers to special districts) played a key role in the development and the morphology of high-rise buildings in different stages throughout Manhattan.

Mohamed et al. [20] developed a spatial analysis model for the allocation of high-rise buildings by integrating GIS with the Analytical Hierarchy Process (AHP). The study incorporated several spatial criteria related to urban characteristics and used them to evaluate the relative suitability of different locations for high-rise development. The study demonstrates the applicability of GIS-based multi-criteria analysis for supporting high-rise building site allocation decisions in urban areas.

Munn and Dragičević [21] proposed a three-dimensional weighted linear combination multi-criteria evaluation (3D WLC-MCE) method for assessing the suitability of residential units within high-rise developments in dense urban environments. Applied to the City of Vancouver, the approach evaluated alternative preference scenarios using spatial criteria that vary vertically within buildings. The results showed that the suitability of residential units can differ according to floor level, orientation, exposure to road-related noise and pollution, sunlight access, and views. The study demonstrates the potential of extending conventional GIS-based multi-criteria evaluation into a three-dimensional urban context to support planning and assessment of vertical development.

Mansouri Daneshvar et al. [22] discussed the problem of land suitability assessment for constructing high-rise buildings in urban sustainability in the Iranian city of Mashhad by proposing an integrated land suitability assessment methodology based on the GIS and ANP approaches. A broad spectrum of indicators based on economic, social, natural, environmental, infrastructure, and environmental services is analyzed. The results indicate that there are low suitability zones in the city even though it has a large number of high-rise buildings due to seismic fault lines, steep slopes, and flood risk in the respective areas. The research validates the fact that such a current trend is really not in line with natural sustainability in such areas.

In analyzing the evaluation process for high-rise buildings for suitable sites in the urban space of Vilnius, Tamošaitienė et al. [9] studied experiences of other European cities. A multi-stage evaluation model based on a combination of three decision-making procedures, SWOT analysis, the determination of the weights of criteria using expert

judgement, and the simple additive weighting method (SAW) to rank the alternatives was developed. The results show that the three methods above are able to reduce the identification of high-rise building locations and contribute to balancing the management's goal and the real estate market.

This paper addresses this issue by applying a multi-criteria geospatial framework that combines spatial analysis and GIS, while adapting the selection criteria and their weights to the local characteristics of the Karrada District in Baghdad—a model for high-density cities in Baghdad—which then becomes a relevant test case, exposing the model's possibilities to solve real city problems. This paper contributes to identifying a set of local planning considerations and transforming them into measurable and comparable spatial criteria within a unified model to support the strategic spatial assessment of high-rise development sites. Furthermore, combining spatial criteria into a single model provides a more comprehensive basis for comparing sites compared to relying on a single indicator.

Finally, the relative weights of the criteria can be adapted when applying the approach in other urban contexts, depending on local characteristics and data. This research can go beyond the particular local "solution" to make a tangible contribution to the theme "sustainable urban growth management". The framework provides a tool for initial spatial screening that helps planners identify areas worthy of further detailed studies, with the possibility of adapting its criteria and weights according to the characteristics of the urban context in which it is applied.

2. CONCEPTUAL FRAMEWORK

2.1 The historical context for the development of high-rise buildings

From a broader urban-planning perspective, the introduction of new development patterns within established urban fabrics can be understood as part of the wider process of urban transformation toward sustainability [23].

Cities and human communities have always relied on the vertical construction pattern throughout history. Many of these emerged for specific purposes that required a larger surrounding area, such as lighthouses, pyramids, ziggurats, and temples in the Sumerian, Babylonian, Egyptian, Greek, and Roman civilizations, as well as the bell towers of cathedrals and churches and the minarets of mosques [24]. The first and oldest example of vertical construction in the Arab world, and indeed the world, dates back to the 16th century AD in the city of Shibam, Hadhramaut, eastern Yemen, famous for its multi-story houses, some of which reached 11 (30 meters) stories high. The inhabitants used this vertical style to protect their families from Bedouin attacks, as this model and orientation represent a departure from the trend of tall buildings from architectural symbolism to a functional transformation, as it came for protection more than other formal aspects. Its importance has multiplied to the point of being called the Manhattan of the Desert (Figure 1) [25].

In the modern era, specifically the mid-19th century, it is worth noting that the invention of the elevator by Elisha Otis in 1852 was the decisive factor that made these buildings more efficient and effective, and helped propel their popularity in American cities, particularly in Chicago and New York [26]. Chicago arguably pioneered the concept of high-rise buildings, with the Home Insurance Building, completed in

1885, considered the first modern steel-framed skyscraper in the modern planning trends of the early 20th century [7]. The leadership in high-rise buildings then shifted to New York, where the city witnessed the emergence of unforgettable architectural icons such as the Empire State Building, completed in 1931, and the Chrysler Building [27]. These buildings were not merely workplaces; they also became the economic identity of modern American cities, especially after World War II (Figure 2(A) and (B)).



Figure 1. City of Shibam in Yemen (Aerial view)

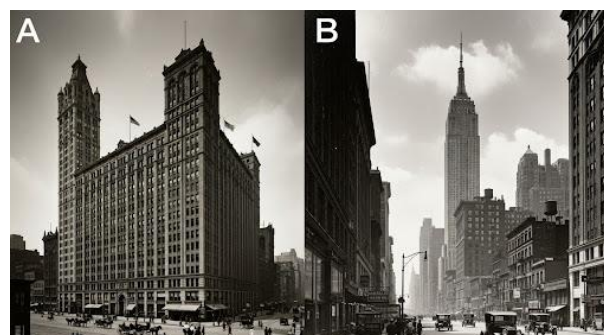


Figure 2. (A) Home insurance building in Chicago, (B) Empire State Building in New York

The increasing population growth, especially in developing countries, has led to horizontal expansion, with populations exceeding ten million (metropolises). This, coupled with the diversity of social and economic functions and increasing land consumption, has impacted the environmental aspects of cities, calling for the use of different methods and perspectives based on the factors influencing their growth [28]. Here, the vertical orientation was inevitable, in line with the development of transportation and other services. High-density urban development should be integrated with transportation systems, as the relationship between population density, transit coverage, and public transport use can significantly influence the efficiency of the urban structure [29]. It is also necessary to integrate high-rise buildings with other urban systems (transportation, energy, and infrastructure) to ensure that the modern city is sustainable, responsive, and adaptable to the conditions it faces [3]. As for the Arab region, specifically the Gulf, Dubai was among the first cities to highlight architectural landmarks of high-rise buildings to market the city as a global economic destination. Examples include Dubai International Center (1979), which reached a height of 149 meters, Burj Al Arab (1999), which reached a height of 321 meters, and most recently, Burj Khalifa (2005), which reached a height of 828 meters (Figure 3(A), (B), (C)) [30].



Figure 3. (A) Dubai International Center, (B) Burj Al Arab, (C) Burj Khalifa

The spatial relationship between built mass and open space also plays an important role in shaping urban form, as variations in building density, spatial enclosure, street dimensions, and surrounding green areas can influence the functional, environmental, and human performance of urban spaces [31]. Based on the above, high-rise buildings today are more than just a means of increasing population density. They play a vital role in shaping the urban fabric and providing multifaceted solutions through:

1) Land-use efficiency: High-rise buildings are an effective solution in cities suffering from land scarcity, as they allow for accommodating large numbers of people and jobs within a small geographic area, reducing the need for horizontal expansion (Urban sprawl) and preserving agricultural land and natural areas [32, 33].

2) Improving infrastructure efficiency: Concentrating populations and activities in vertical areas contributes to improving the efficiency of infrastructure and public services such as transportation networks, water, and electricity. This concentration decreases everyday distances travelled by people, which helps to fight against traffic jams and carbon emissions, and decreases overall costs of providing such services [34, 35].

3) Urban icons and urban landmarks: High-rise buildings can often even become icons in the city and become a type of landmark for people outside the city, which further improves its economic and cultural significance globally [36].

4) Advancing and encouraging mixed land use: Mixed use has been pioneered with the modern construction of high-rise buildings which integrate housing, office, retail and entertainment spaces in one building, thereby creating a so-called "vertical city" that minimizes the need for transport and aims to produce a fully fledged living environment [37].

2.2 Geospatial framework for high-rise building site planning in dense urban areas

The use of new geospatial technologies is combined with an integrated methodological approach that will meet all these challenges that might arise in the site planning process of a high-rise building in an urban area with city infrastructure and other negatively influencing elements. The conceptual framework is based on a precise scientific merger between the abilities of GIS in discussing intricate spatial patterns and spatial multicriteria analysis in the direction of determining the impact of factors in planning and selecting a site in which to build high-rises. These analytical capacities enable the merging of several impacts of spatial criteria in the planning decision-making process. Past studies have shown that GIS

can facilitate sustainable planning in urban areas through the integration and analysis of various spatial data sources about urban growth, population distribution, infrastructure, accessibility and environment, people and goods movement, etc., and can provide a holistic spatial platform to support decisions in urban planning [38].

This framework is intended to have three methodological bases that are tied together to be analytically effective. The spatial analysis capability of GIS is the first pillar that allows the integration, visualization, and analysis of various types of spatial and non-spatial data related to urban planning. GIS can be used to assist in the analysis of urban development patterns, land use, infrastructure, accessibility, environmental conditions, and spatial distribution of urban services, which can aid in the decision-making process for informed planning [39]. The second pillar (spatial multicriteria analysis methodology) provides a systematic way of taking, weighing, and evaluating several overlapping criteria. As we know, these criteria are not equally impactful and have different intensities on the phenomenon that we are studying. There is a hierarchical structure with multiple levels: starting with strategic criteria (sustainability, economic efficiency...), intermediate functional criteria, and detailed (operational) indicators. This methodology uses systematic pairwise comparisons and consistency measures to check the logical coherence of the judgments and enhance the reliability of the priorities obtained [40]. The third pillar involves integrating spatial analysis tools with the relative weights of criteria to produce spatial suitability maps based on the data and criteria used in the model, with the possibility of conducting advanced weight robustness and ranking stability analyses [41].

Based on the above topics in the planning for high-rise buildings, the impact of geospatial techniques, the hierarchical analysis process, and the literature listed in the introduction, it is possible to come up with a set of factors influencing the planning of these sites, which can be inputs that will be clarified in the methodology to identify the sites for constructing high-rise buildings, and they are as follows:

A. Environmental Factors

1). **Distance from natural and historical sites:** Such as orchards, rivers, marshes, and lakes, and agricultural lands that affect productivity for city residents, aesthetic appeal, and the availability of green spaces for urban dwellers.

2). **Distance from seismic activity zones:** To avoid catastrophic impacts that may result from geological movements; thus, it is unsuitable for constructing high buildings to prevent the collapse of skyscrapers.

B. Social indicators

1). **Proximity to low population density:** Where vertical housing can be constructed without harming existing services and the current urban residential spaces, particularly avoiding psychological and social harm to residents of adjacent horizontal housing.

C. Economic indicators

1). **Distance from current commercial centers:** To establish a new business hub and avoid congestion in older centers.

2). **Distance from high-cost land:** For easier ownership and construction, and to provide spatial and economic savings for the selected area, since land prices in the city vary based on many factors, including location near the urban or commercial center.

D. Physical indicators

1). **Proximity to main transportation routes:** To

contribute to the establishment of a new business district, facilitate the movement of residents of residential complexes, and attract individuals to live in these complexes.

2). Proximity to undeveloped land suitable for construction: This is aimed at attracting residential density to these areas and shifting housing patterns from horizontal to vertical.

3. MATERIALS AND METHODS

3.1 Research design and analytical framework

A combined methodology, incorporating descriptive analysis and spatial analysis, was employed to identify the most suitable locations for high-rise buildings within the Karrada District of Baghdad. This methodology combined GIS and multi-criteria analysis, which consisted of different aspects that affect the siting process (environmental, social, economic, and physical aspects) being represented in spatial layers, which are measurable, analyzable, and comparable. The methodology has several stages, which are interconnected. It started by defining the research problem and reviewing the literature related to planning of buildings of heights (high-rise) and site selection. Next, the criteria influencing the selection process were identified. This was followed by the collection of spatial and descriptive data from relevant stakeholders, their integration into digital databases within a GIS environment, and the extraction of standardized digital layers. The relative importance of the criteria was determined based on expert opinions and using hierarchical analysis. Finally, the criteria layers were reclassified and

integrated within the GIS environment to produce the final spatial suitability map.

3.2 Study area

Baghdad, the capital of Iraq, is one of the most densely populated cities in Iraq and the Middle East. The city has undergone numerous transformations throughout its morphological development, which have impacted land use, particularly the shift from residential to commercial use. This shift has led to various problems, including traffic congestion, environmental pollution, visual pollution, and functional disruptions. The Al-Karada area is located in the southeast of Baghdad, bordered to the north by the Rusafa District, to the northeast by the New Baghdad district, to the south by the Al-Jisr district, to the west by the Al-Mamoun district, and to the northwest by the Karkh district, as shown in Figure 4.

The Al-Karada area consists of 9 main sectors or quarters, each containing a group of neighborhoods, as shown in Table 1 based on the official neighborhood map issued by the Baghdad Municipality. The study area used in the analysis is 7,454.72 hectares, based on the land use database used in the study. Geographically, the Al-Karada area is situated between longitudes ($44^{\circ}21'27''$ - $44^{\circ}30'53''$) East and latitudes ($33^{\circ}13'12''$ - $33^{\circ}19'17''$) North [42]. Karrada District is distinguished by several geographical features within the Baghdad Governorate, most notably its central location in the province. It is bordered to the northeast by the Mohammed Al-Qasim Highway, while the Tigris River wraps around it from the northwest to the southwest. It is also administratively divided into 9 residential quarters, and these are divided into residential neighborhoods, as shown in Table 1.

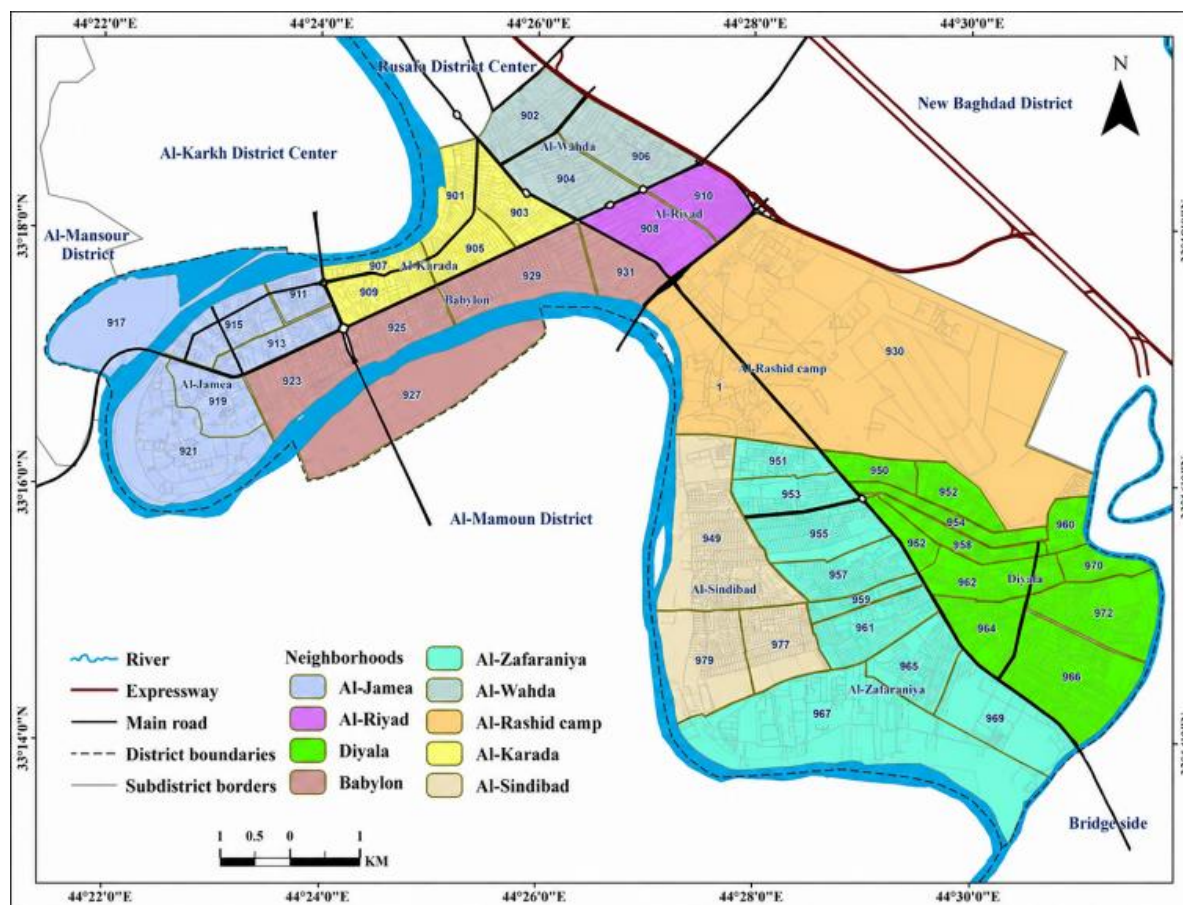


Figure 4. Quarters and neighborhoods of the Karrada District in Baghdad

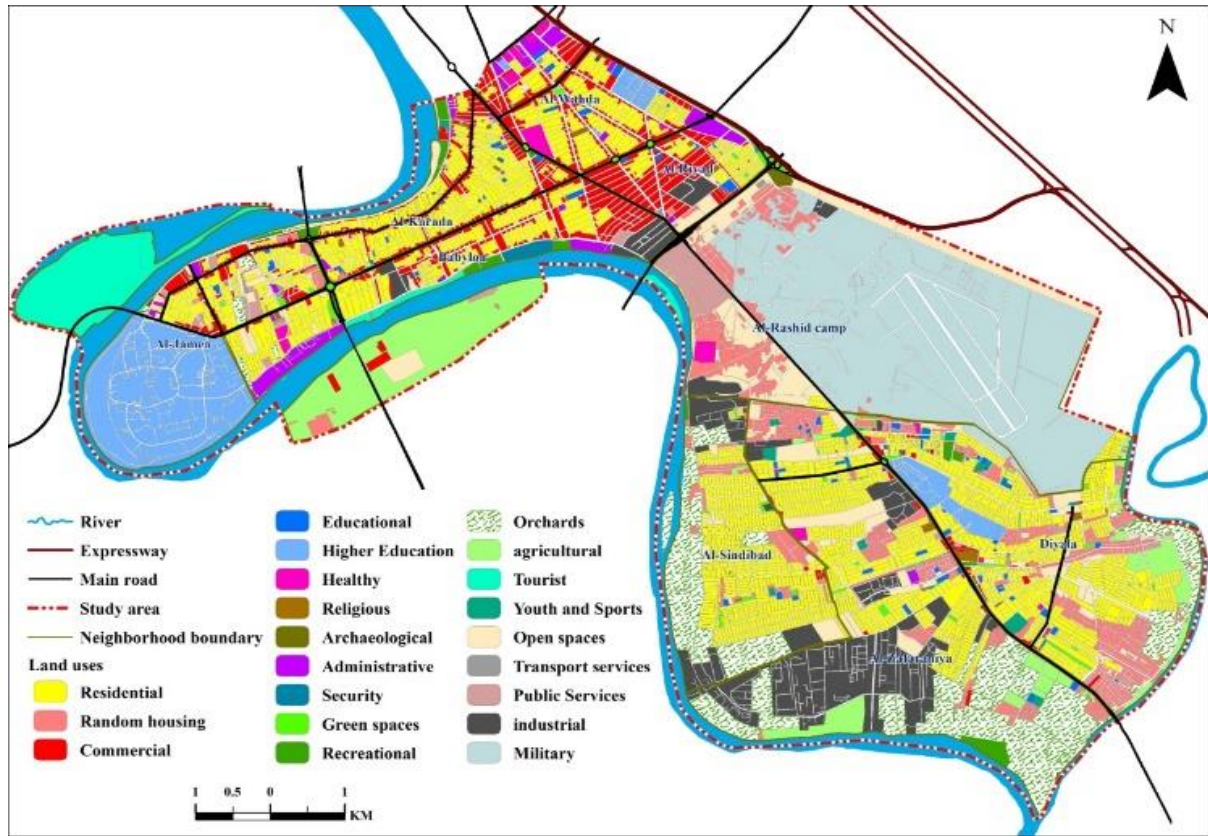


Figure 5. Land use distribution of the Karrada District in Baghdad

Table 1. Number of neighborhoods for Karrada quarters

No.	Quarter Name	No. of Neighborhood
1	Al-Jamea	911, 913, 915, 917, 919, 921
2	Al-Zafaraniya	951, 953, 955, 957, 959, 961, 965, 967, 969
3	Al-Karada	901, 903, 905, 907, 909
4	Al-Wahda	902, 904, 906
5	Al-Sindibad	949, 977, 979
6	Al-Riyad	908, 910
7	Babylon	923, 925, 927, 929, 931
8	Diyala	950, 952, 954, 956, 958, 960, 962, 964, 966, 970, 972
9	Al-Rashid camp	1, 930

Additionally, the area is home to numerous universities, the most prominent being the University of Baghdad and the University of Nahrin, and it includes a variety of diverse uses such as commercial centers, factories, public services, and more (Table 2 and Figure 5).

There is also an extensive network of various transportation routes, with the total length of highways measuring 16.89 km, main roads 102.14 km, and secondary roads 112.9 km [42, 43].

The scarcity of high-rise buildings in Baghdad and the Karrada District, despite its strategic and attractive location, is due to many reasons, including:

- 1). The absence of a comprehensive plan for the construction of high-rise buildings, the absence of building regulations and laws that permit their construction, and the setting of height limits that do not exceed certain limits.
- 2). The failure to update the general plan for the city of Baghdad to ensure the construction of this type of building.
- 3). The lack of interest from the public and private sectors in constructing this type of building.
- 4). The lack of sufficient land in the city center.

5). The need for sufficient parking spaces, adequate road capacity, and appropriate infrastructure services should be considered in planning high-rise development, particularly in Baghdad, where previous research has demonstrated that changes in urban land use can substantially increase parking demand and traffic pressure [44].

6). The lack of sufficient local technology and expertise, and the need for foreign expertise in this field.

Table 2. Land use areas and their percentage for the Karrada District in the city of Baghdad

No.	Land Uses	Area (ha)	Percentage (%)
1	Residential	1,280.76	17.18
2	Random housing	395.03	5.30
3	Commercial	339.23	4.55
4	Educational	45.92	0.62
5	Higher Education	384.20	5.15
6	Healthy	44.27	0.59
7	Religious	20.41	0.27
8	Archaeological	5.33	0.07
9	Administrative	83.70	1.12
10	Security	13.18	0.18
11	Green spaces	45.77	0.61
12	Recreational	44.39	0.60
13	Youth and Sports	24.18	0.32
14	Open spaces	367.24	4.93
15	Orchards	557.17	7.47
16	Agricultural	338.63	4.54
17	Transport services	15.76	0.21
18	Transportation routes	1,124.02	15.08
19	Public Services	77.61	1.04
20	Industrial	421.46	5.65
21	Tourist	209.57	2.81
22	Military	1,046.02	14.03
23	Rivers and water bodies	570.87	7.66
	Sum	7,454.72	100

3.3 Data sources and spatial database setup

As for the data sources, we relied on the literature related to the subject of the study, both in the conceptual aspect and the applied framework, as the data were collected for the study area from different directorates and departments such as the Karrada Municipality and the Baghdad Municipality, in addition to the Central Statistical Organization in the Ministry of Planning; GIS was used to generate relevant complex data such as population densities and other sources available in scientific articles and published in global containers regarding the study area. The study period was April to October 2025, and the necessary data for the study were collected. The data included land uses, road networks, population, natural and historical sites, seismic activity zones, commercial centers, land values, and undeveloped and buildable land. These data represent the actual inputs to the current model, whereas detailed data on geotechnical characteristics, groundwater, flooding, network capacities, elevation constraints, regulation, and ownership were not targeted with sufficient uniform spatial accuracy to be included in the comparison model at the study area level. These were not included as they would be addressed during the site-level verification process at a detailed level, which is not part of the present strategic screening model. The data were entered into a GIS environment, and the coordinate system and spatial accuracy of all layers were standardized. Data were subsequently checked, geometric and topological errors were edited out, and the boundaries of the layers were checked to correspond to the study area boundaries. If data were in descriptive form or paper form, then it was digitized and georeferenced to the spatial location. All the layers that were utilized in the analysis were then assembled in a single spatial database.

3.4 Identifying suitability factors and criteria

The criteria that affect the selection of high-rise building sites were determined by literature, study area characteristics, and experts' opinions. These criteria were put into four broad categories, namely, environmental factors, social factors, economic factors, and physical factors. Two environmental factors were considered: distance from natural/historical sites, and distance from seismic activity areas. The social factor was represented by proximity to areas with low population density. Economic considerations were distance from existing commercial centers and distance from high-value land. Physical factors included closeness to major transportation systems and closeness to undeveloped/buildable land. Before the analysis, the directionality of the influence of each criterion was determined – the higher the value for a site, the “more suitable” the site was; the lower, the “less suitable.” For criteria representing sources of risk, sensitivity, or cost, such as seismic activity zones, natural and historical sites, and high-value land, suitability increases with distance. Conversely, for criteria related to accessibility and land availability, such as main roads and undeveloped buildable land, suitability increases with proximity (Table 3).

The current model does not use a separate layer for legal or exclusionary restrictions. Therefore, the resulting classification represents a relative spatial suitability according to the seven criteria, not a final judgment on developability. The transition from spatial suitability to development feasibility requires subsequent examination of military lands, protected areas, riverbanks, heritage sites, orchards, and

legally restricted lands. Also, the current model is limited to a strategic spatial assessment using criteria that can be consistently represented spatially at the area study level. It does not aim to provide a final plot-level evaluation or issue a direct construction decision. Therefore, some detailed constraints requiring high-resolution site or regulatory data, such as geotechnical properties, groundwater depth, flood risk, flight height restrictions, capacity of water, drainage, energy, road, and public transport networks, fire service access, plot geometry, ownership, regulatory controls, building coefficients, wind and shading effects, and privacy, have not been incorporated. These factors must be verified at a later stage before moving from spatial suitability to actual development viability.

Table 3. Direction of preference and suitability function for the selected criteria

Criterion	Preference Direction	Higher Suitability Corresponds to	Planning Rationale
Distance from natural and historical sites	Increasing with distance	Greater distance	Protection of sensitive natural and heritage resources
Distance from seismic activity zones	Increasing with distance	Greater distance	Reduced exposure to seismic hazard
Proximity to low population density	Increasing with proximity	Lower-density areas	Lower existing development and population pressure
Distance from existing commercial centers	Increasing with distance	Greater distance	Reduce over-concentration and support secondary development centers
Distance from high-value land	Increasing with distance / lower land value	Lower-value land	Improve economic feasibility
Proximity to major transportation routes	Increasing with proximity	Shorter distance	Improve accessibility and connectivity
Proximity to undeveloped buildable land	Increasing with proximity	Greater access to buildable land	Improve land availability for development

3.5 Determining the weights of criteria using hierarchical analysis

The research used the AHP to find out relative significance among criteria. This has a benefit as it brings organization to the decision problem, enables the criteria to be considered on a pairwise basis, and checks the logical consistency of the decisions taken. In this context, seven experts who have relevant expertise in the field of the study participated. These disciplines comprised urban and physical planning, GIS, transportation planning, environmental planning, civil engineering, and real estate development. The experts were selected based on their expertise in land use, urban development, suitability assessment, and site selection. Each expert was asked to compare the seven criteria pairwise using

the Saaty scale, which ranges from 1 to 9. A value of 1 indicates that the criteria are equally important, while values 3, 5, 7, and 9 indicate moderate, strong, very strong, and maximum importance, respectively. Values 2, 4, 6, and 8 were used to represent intermediate cases, while inverse values were used when a row criterion was less important than a column criterion. Since the number of criteria was seven, the number of independent pairwise comparisons performed by each expert was 21, according to the relationship:

$$N = \frac{n(n-1)}{2}$$

where,
N: Number of pairwise comparisons.
n: Number of criteria.

The experts used the Saaty scale for pairwise comparisons, with the following scores (Table 4):

Table 4. Saaty binary comparison scale

Degree of Comparison	Significant
1	The two criteria are of equal importance.
3	One criterion has a moderate preference.
5	One criterion has a strong preference.
7	One criterion has a very strong preference.
9	One criterion has an extreme preference.
2,4,6,8	Intermediate values between the previous judgments.
Inverse values	Used when one criterion is less important than the other.

The following symbols, C1, C2, ..., C7, were used to represent the criteria selected in the study, as shown in Table 5:

Table 5. Codes of criteria used in the analysis

Criteria	Code
Distance from natural and archaeological areas	C1
Distance from lines of earthquake activity	C2
Proximity to low population density	C3
Distance from commercial centers	C4
Distance from high-cost land	C5
Proximity to main transportation routes	C6
Proximity to undeveloped land suitable for construction	C7

Based on this, an expert evaluation form was developed, as shown in Table 6.

The experts' judgments were converted into independent pairwise comparison matrices, with each criterion compared to the others on the Saaty scale. Values on the main diagonal represent the case where the criterion is equal to itself, and are therefore assigned a value of 1. Values above the main diagonal represent the preferences, and values below the diagonal represent the inverse values of their corresponding comparisons. After creating a matrix for each expert, the individual judgments were combined into a single group matrix using the geometric mean, as this is the most suitable method for grouping the judgments of a group of experts while preserving the reciprocity of the pairwise comparisons. The following matrix shows the final group values for the comparisons between the criteria (Table 6).

Table 6. Group pairwise comparison matrix of criteria

Criteria	E1	E2	E3	E4	E5	E6	E7
C1	1.000	0.806	0.600	0.765	0.654	0.756	0.533
C2	1.241	1.000	1.161	1.132	0.811	1.183	0.649
C3	1.667	0.862	1.000	1.308	1.028	1.210	0.710
C4	1.308	0.883	0.764	1.000	0.656	0.861	0.664
C5	1.528	1.233	0.972	1.525	1.000	1.278	0.701
C6	1.323	0.845	0.826	1.162	0.782	1.000	0.717
C7	1.875	1.542	1.409	1.506	1.426	1.395	1.000

After preparing the collective matrix, its values were normalized by dividing each element by the sum of its column. The normalization process is undertaken to transfer the values to the standardized values defined on a scale for determining the relative weightages of the various criteria. Then, the average of the normalized values in each row was calculated to obtain the priority vector representing the relative weights of the criteria with respect to the following formula:

$$r_{ij} = \frac{a_{ij}}{\sum_{k=1}^n a_{kj}}$$

where, *r_{ij}*: normalized value of criterion *i* in column *j*; *a_{ij}*: original pairwise-comparison value between criteria *i* and *j*; $\sum_{k=1}^n a_{kj}$: sum of the elements in column *j*; *n*: number of criteria.

Then, the average of the standard values in each row was determined, from which the priority vector denoting the relative weight of the standards was obtained as:

$$w_i = \frac{\sum_{j=1}^n r_{ij}}{n}$$

where, *w_i* represents the relative weight (priority weight) of criterion *i*, *r_{ij}* is the normalized value of criterion *i* in column *j*, and *n* is the number of criteria.

Table 7. Relative weights and ranking of criteria

Rank	Criteria	Relative Weight	%	≈ %
1	Proximity to undeveloped land suitable for construction	0.19997	19.997%	20%
2	Distance from high-cost land	0.15947	15.947%	16%
3	Proximity to low population density	0.15056	15.056%	15%
4	Distance from lines of earthquake activity	0.14054	14.054%	14%
5	Proximity to main transportation routes	0.12985	12.985%	13%
6	Distance from commercial centers	0.11938	11.938%	12%
7	Distance from natural and archaeological areas	0.10022	10.022%	10%
Total		1.00000	100%	100%

The analysis showed that the weightage of the most important criterion is proximity of undeveloped and buildable land with 20% weightage, as land availability is essential for the feasibility of high-rise building projects. The second most important factor (16%) was distance from high-value land,

while the third (15%) was near low-density areas. The distance to seismic activity was given 14% weight, and distance to major transportation was given 13% weight. The weight was allocated to be 12% for distance from existing commercial areas, and the least was given to distance from natural and historical sites (10%). The weight for a criterion does not necessarily reflect the criterion's importance, but rather how important its contribution was on a relative scale when compared to the other criteria in the overall model (Table 7).

To ensure the logic of the experts' assessments and the absence of significant discrepancies in the comparisons, the consistency of the judgments was examined by calculating a consistency index and a consistency ratio. A consistency ratio of 0.10 was used as the upper bound; a ratio below this threshold is considered consistent. Responses exceeding this threshold would need to be reviewed, and some of the comparisons will be reassessed and added to the final weights.

$$C=\frac{\lambda_{max}-n}{n-1}$$

$$CR=\frac{CI}{RI}$$

where, CI is the consistency index; λ_{max} is the maximum eigenvalue of the pairwise comparison matrix; n is the number of criteria; RI is the random consistency index; CR is the consistency ratio.

The relative weights vector was then extracted, and the matrix of group pairwise comparisons was multiplied by the relative weights vector to get the weighted vector of pairwise comparisons. The values of the weighted vector were then divided by their corresponding weighting, and the values were averaged to get the value of the largest eigenvalue of the matrix. The largest eigenvalue obtained was 7.0264, which is nearly equal to the number of the criteria (7), which suggested high consistency in the pairwise comparisons.

The individual expert matrices were aggregated using the geometric mean to construct a single group pairwise-comparison matrix. Because the original individual consistency calculations were not retained as separate analytical outputs, consistency was evaluated at the aggregated group-matrix level. The resulting group matrix produced a consistency ratio of 0.0033, which is well below the accepted threshold of 0.10 and indicates a high level of internal consistency in the aggregated judgments. Accordingly, the reported consistency measure should be interpreted as a group-level consistency indicator rather than as an individual consistency ratio for each expert.

A separate inter-expert agreement statistic could not be calculated retrospectively because the individual expert response matrices were not retained as separate datasets after aggregation. This is acknowledged as a limitation of the expert-weighting stage.

3.6 Processing standards layers and implementing spatial matching

This included the generation of spatial databases in a GIS environment in multiple layers to enable the comparison and combination to produce a single spatial suitability model. The following steps were carried out: Layering in the first step was done based on the nature of each criterion. Using the Euclidean distance tool, distances from the study-area criteria features, such as the main roads, commercial centers, natural areas, historical areas, seismic activity areas, and spatial features,

was calculated. Categories were created from the descriptive and spatial information for each layer, such as population, land values, and undeveloped land available for building, and were then transformed into analyzable cellular layers. Second, the values of each layer have been reclassified to a common scale from 1 (low) to 10 (good).

For criteria C1, C2, C4, and C5, higher values were awarded to sites that achieved a greater distance from the measured element or were located within the least valuable land, while for criteria C3, C6, and C7, higher values were awarded to sites that were closest to the preferred condition represented by low population density, proximity to main roads and availability of undeveloped buildable land.

At this stage, the classification trend to be followed was decided, based on the impact and type of each criterion. Examples include rating sites near major transportation routes highly, rating sites farther away as less buildable, and assigning low ratings as sites approach to the seismic activity zones or natural and historical sites. Likewise, low-value land in low-population areas was given a higher score than high-value land in high-population areas. Third, inside the GIS environment, the layers were merged using weighted overlay. This means that the value assigned to each cell in the matrix is multiplied by the relative weight assigned to the criterion in the matrix, and the values for each site (cell) within the study area are added together to give the final suitability score for each site. The above relationship was used to express the suitability model:

$$S = \sum_{i=1}^n w_i x_i$$

where,

S : Final spatial fit value.

w_i : Relative weight of the criterion.

x_i : Standard value of the cell within the criterion layer.

n : Number of criteria used in the analysis.

3.7 Weight robustness and ranking stability analysis

The robustness of the relative weights used in the model was tested by examining how the ranking of criteria was affected by hypothetical changes in weights derived from expert judgments. Two scenarios were created for each criterion: increasing its weight by 20% and decreasing it by 20% compared to the base weight, with the difference being redistributed proportionally to the remaining criteria so that the total weights in each scenario remain equal to 100%. The adjusted weight of the criterion under test was calculated using the following formula:

$$w_i^* = w_i (1 \pm 0.20)$$

The weights of the remaining criteria were calculated according to the following formula:

$$w_j = w_j * \frac{(1 - w_i^*)}{(1 - w_i)}$$

where, w_i represents the original weight of the criterion under test, and w_i^* represents its adjusted weight, while w_j represents the original weight of any other criterion, and w_j^* represents its weight after redistribution.

This resulted in fourteen alternative scenarios, one

increasing and one decreasing scenario for each of the seven criteria, in addition to the baseline scenario (see Table A1).

After calculating the adjusted weights for each scenario, the weight structure and ranking of criteria were compared with the baseline scenario to determine the stability of priorities in relation to weight changes.

Each scenario was also compared to the baseline scenario in terms of the order of criteria and the change in their relative positions within the priority scale. Spearman's rank correlation coefficient was used to measure the degree of similarity between the criterion order in each scenario and the baseline order, according to the following relationship:

$$\rho = 1 - \frac{6 \sum d_i^2}{n(n^2 - 1)}$$

where, ρ represents Spearman's correlation coefficient, and d_i represents the difference between the rank of the criterion in the baseline scenario and its rank in the modified scenario, while n represents the number of criteria, which is seven (see Table A2), which uses the scenario of increasing the weight of criterion 1 (C1) by 20% as a computational example, and the same applies to the rest of the scenarios.

Substituting into Spearman's equation yielded $\rho = 0.964$. Values close to 1 indicate high stability of the criteria order, while lower values indicate greater variability in priority ranking. The same steps were applied to the remaining scenarios. Correlation coefficients, comparison results, and their interpretation are presented in the Results and Discussion section.

Weight sensitivity analysis is commonly used in AHP-based multi-criteria decision models to examine the extent to which changes in criterion weights affect the stability of priority structures and decision rankings [41]. The weight robustness analysis in this study was limited to testing the stability of weights and criteria order and did not include re-implementing the spatial fit model for each scenario.

Therefore, it was used as a weight structure test, not a comprehensive spatial sensitivity test of the outcomes.

3.8 Final spatial suitability map classification

After applying the weighted overlay model and integrating the seven criteria layers according to their relative weights, a spatial map of suitability values ranging from low to high was generated. To make the results easier to interpret and compare spatially, the results were reclassified into the five suitability classes. The classification relies on dividing the range of suitability values into intervals, and each interval denotes a certain level of site development potential. Low values are sites that do not have the 'most preferred' spatial characteristics, and high values are sites that have a combination of more 'most preferred' spatial characteristics (Table 8).

Table 8. Classification of spatial suitability levels for high-rise building sites

Range of Suitability	Suitability Level	Planning Explanation
0–2	Very low suitability	These sites are affected by multiple spatial constraints and are not recommended for development priority.
More than 2–4	Low suitability	Sites that do not meet a sufficient number of the requirements for constructing high-rise buildings.
More than 4–6	Moderate suitability	These sites can be studied, but they need further improvements or detailed examinations.
More than 6–8	High suitability	Sites that meet most selection criteria and are suitable for detailed planning studies.
More than 8–10	Very high suitability	High-priority sites for conducting subsequent development and implementation studies.

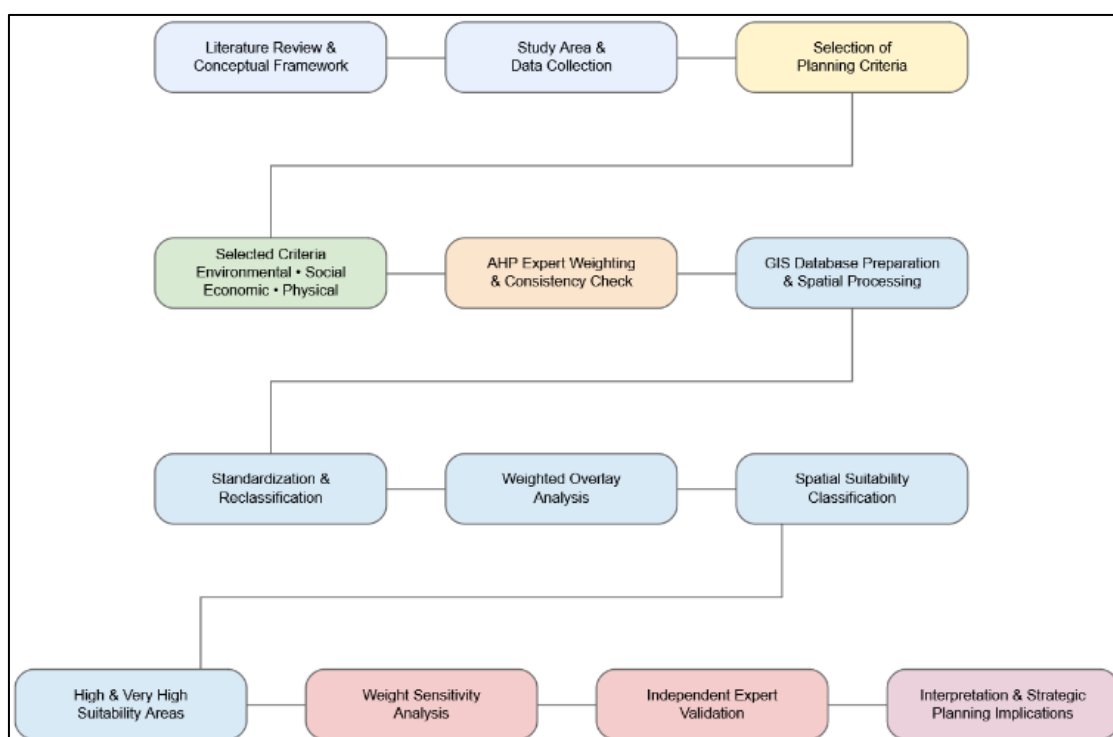


Figure 6. GIS-AHP methodological workflow for high-rise development site suitability assessment

Vertical development priority areas were identified and highlighted by the high and very high categorization. None of the identified areas should be interpreted as being immediately suitable for construction. The map is used to screen sites strategically, and the chosen sites would need more detailed investigations into issues such as land ownership, capacity of the infrastructure network, geotechnical properties, traffic impacts, planning and construction controls (Figure 6).

The current model does not use a separate layer for legal or exclusionary restrictions. Therefore, the resulting classification represents a relative spatial suitability according to the seven criteria, not a final judgment on development feasibility. The transition from spatial suitability to development feasibility requires subsequent examination of military lands, protected areas, riverbanks, heritage sites, orchards, and legally restricted lands.

3.9 Expert-based validation of the suitability results

To verify the planning plausibility of the suitability model outputs independently of the weighting process, the final suitability map and its five categories were presented to a panel of experts who had not participated in the pairwise comparisons used in AHP. They were asked to assess the extent to which the spatial distribution of the categories corresponded to the known characteristics of the Karrada District, the plausibility of the locations classified in the high and very high suitability categories, and the map's suitability as a tool for strategic spatial screening. The assessments were recorded using a five-point Likert scale ranging from 1 (Very Low Agreement) to 5 (Very High Agreement).

For the study design, five experts, independent of the seven experts involved in the AHP weighting process, participated in the validation procedure, as shown in Table 9.

Table 9. Professional background of the independent validation experts

Expert Code	Field of Expertise	Role in the Validation
V-E1	Urban and Spatial Planning	Assessing the planning plausibility of the spatial distribution of suitability classes within the urban fabric.
V-E2	Geographic Information Systems and Spatial Analysis	Assessing the overall spatial consistency of the suitability map and the interpretation of its classification pattern.
V-E3	Transportation Engineering and Planning	Assessing the consistency of the suitability results with accessibility conditions and the major road network.
V-E4	Environmental planning	Assessing the consistency of the suitability results with natural, historical, and environmentally sensitive areas.
V-E5	Land-Use and Urban Development Planning	Assessing the planning plausibility of the identified priority areas in relation to land use and development potential.

The five experts were presented with the final suitability map, the five suitability categories, and the seven criteria used in the model and their relative weights. It was clarified that the

highly rated areas did not automatically qualify for development but were instead priority areas for detailed planning examination. Next, the experts were asked to review the outcome of the exercise on the overall plausibility of the spatial distribution, areas classified as high suitability, areas classified as very high suitability, connection with the planning, transportation, and environmental characteristics of the study area, as well as suitability for the model to support strategic spatial screening using an eight-item questionnaire. The full validation tool is included in Table A3.

The expert ratings were analyzed using the arithmetic mean and standard deviation for each validation item, together with the overall mean score, to assess the planning and spatial plausibility of the model outputs.

4. ANALYSIS OF DATA AND RESULTS

This section discusses the specific spatial criteria mentioned above and selected for use in the study; it shows the results of the weighting, and finally it shows the distribution of the final suitability map for the Karrada District. This section focuses on presenting the patterns and results derived from the analysis; their significance and comparison with previous studies will be discussed in the following section.

4.1 Environmental factors

4.1.1 Distance from natural and archaeological sites

The avoidance of natural and archaeological areas in Al-Karada when selecting sites for high-rise buildings is a crucial step to ensure the establishment of environmental, healthy, and aesthetic zones. Despite the visual and environmental value that natural and historical elements provide to the urban landscape, the study treated them as sensitive elements on which direct urban pressure should be reduced; therefore, the degree of suitability increased as the distance from them increased. They offer an attractive visual backdrop for high-rise buildings and create harmony between nature and urban construction, thereby generating overall appeal for the city. The policy of integrating nature with high-rise buildings has become a standard in advanced cities, contributing to the reduction of urbanization impacts and encroachment on land while promoting the sustainability of the city.

Consequently, Al-Karada is one of the older areas in Baghdad, containing many agricultural lands and natural components. Therefore, the study area has been divided based on the Euclidean Distance tool; the areas closest to agricultural lands and nature reserves are the most unsuitable for such buildings in harmony with sustainability trends that require their preservation, and the greater the distance from sensitive natural and historical sites, the higher the degree of suitability, while sites closer to them received lower scores (Figure 7).

4.1.2 Proximity to lines of earthquake activity

The distance index from seismic activity lines is crucial when selecting sites for high-rise buildings, as it helps avoid catastrophic effects that may arise from ground movements unsuitable for constructing tall structures. Several advantages can be achieved with this index, mainly reducing insurance costs and protecting investments, thus making the real estate market more appealing in terms of safe land. It also alleviates pressure on infrastructure and reduces the need for reconstruction after disasters, boosting investor confidence.

Areas close to seismic activity lines are more susceptible to earthquakes that can cause significant damage, especially to high-rise buildings. Constructing in areas safe from seismic activity provides an opportunity to design more effective structures capable of withstanding harsh natural conditions. This reduces the need for costly and complex building

techniques to address earthquakes. Consequently, by using the Euclidean Distance tool, the areas located on the seismic line are the most unsuitable for constructing high-rise buildings, and suitability increases the further we move away from them within the boundaries of the study area, according to the classification from 1-10, as shown in Figure 8.

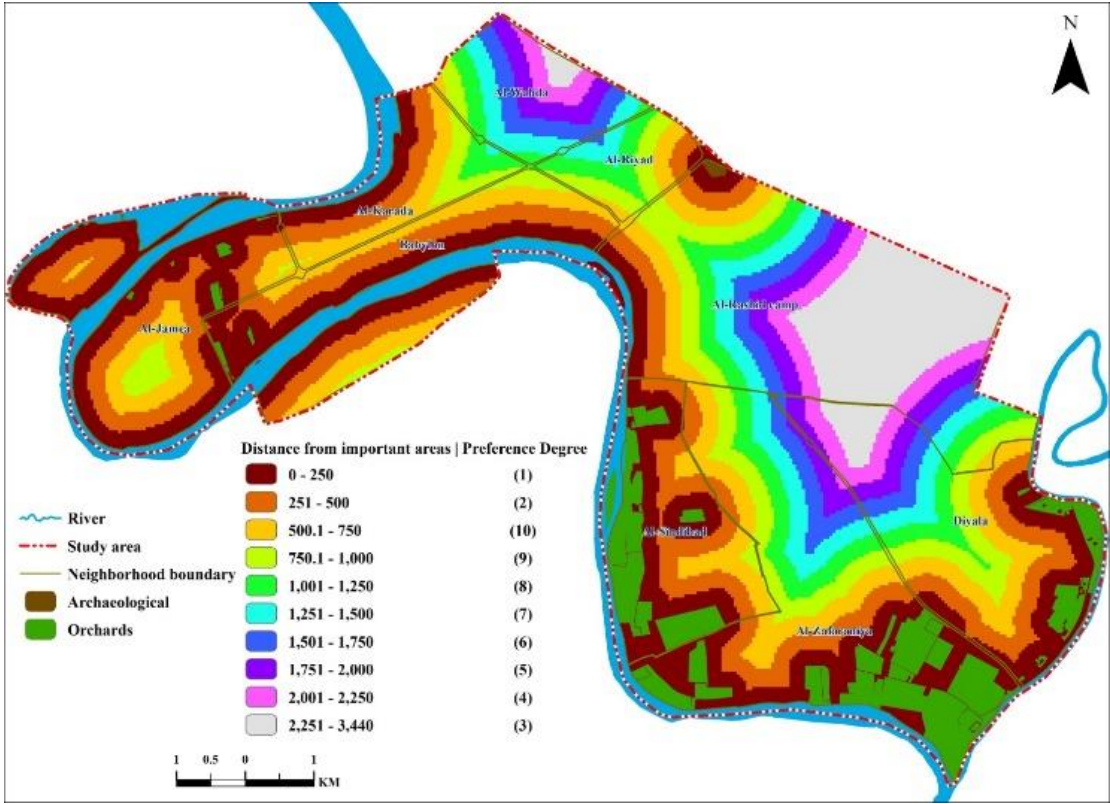


Figure 7. Distance from natural and archaeological areas in Karrada District

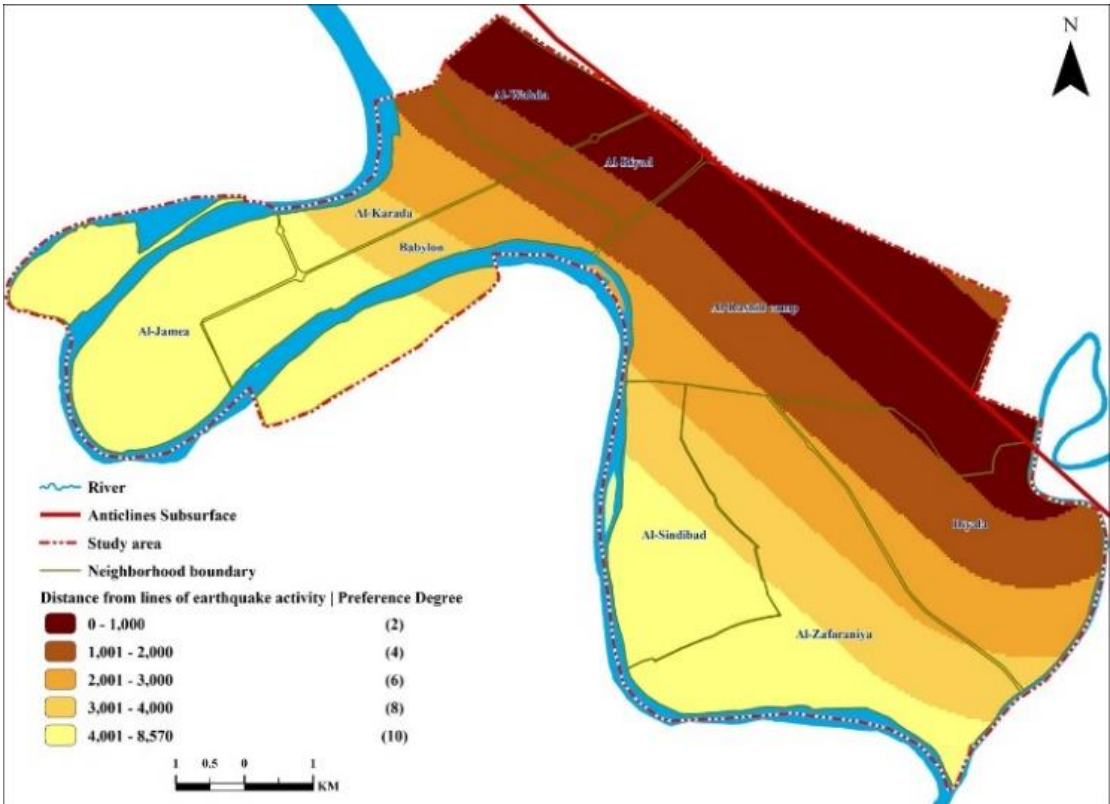


Figure 8. Proximity to lines of earthquake activity in the Karrada District

4.2 Social factors

4.2.1 Proximity to low population density

The proximity of high-rise buildings to areas with low population density leads to the attraction of residential density from horizontal housing to vertical housing. This is a significant factor in selecting locations for high-rise buildings, as constructing high-rise buildings can be considered an effective alternative to traditional horizontal housing, especially in cities experiencing rapid population growth and rising land prices, as is the case in Baghdad and specifically in the Karrada area. This also contributes to strengthening social interaction between members of society, as tall buildings by their nature make residents meet more outside their homes, with the presence of large spaces provided by the urban environment within these communities, unlike spaces in horizontal residential areas, as the large area of the units will make the periods of staying inside the home longer than

outside, and thus will work to reduce the vitality of spaces in horizontal residential environments. Utilizing vertical spaces instead of horizontal ones alleviates pressure on limited land and provides a wide range of services and facilities, such as shopping centers, sports clubs, and recreational, health, and community facilities, which attract residents seeking a modern and comfortable lifestyle. Additionally, high-rise housing can help distribute the population over larger areas, thereby reducing the pressure on existing infrastructure in densely populated regions. Consequently, the closer we get to areas with low density, the greater the preference for attracting residents from high-density areas. Residential neighborhoods have been categorized based on their population density, assigning the highest rating to areas with low population density (10) and the lowest rating (1) to areas with high population density, as illustrated in Figure 9, which shows the residential densities in the study area.

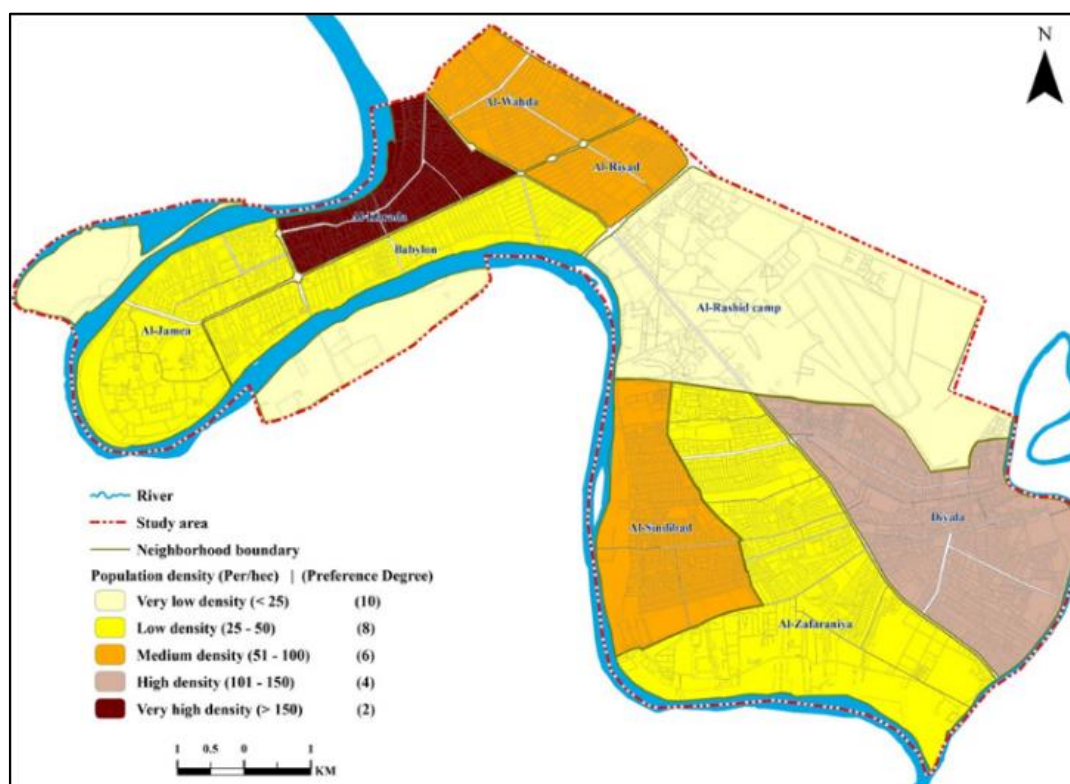


Figure 9. Proximity to low population density in the Karrada District

4.3 Economic factors

4.3.1 Distance from existing commercial centers

It is preferable to avoid the existing commercial centers in the Karrada area to establish a new commercial center for high-rise buildings, which will include business gathering centers. This is essential for achieving economic and social balance in the region. This indicator helps distribute commercial activities and alleviate pressure on the current infrastructure, as well as avoid creating unbalanced competition between the existing centers and the new center in the selected locations. Such a situation could lead to the dispersion of commercial activities and harm existing businesses. Consequently, a balanced distribution of economic activities in the area contributes to reducing pressure on a specific area and distributes traffic and commercial activities more broadly. Based on this, the Euclidean Distance tool was

used to measure the distance from existing commercial centers. Sites further from these centers received higher suitability scores, while the score decreased as the site got closer to existing commercial activity centers, consistent with reducing excessive concentration of activities and encouraging the formation of secondary development centers (Figure 10).

4.3.2 Distance from high-cost land

Proximity to low-cost land areas is an important factor in the construction of high-rise buildings due to the ease of acquiring such land. Cheaper land contributes to reducing the costs of high-rise buildings and increases the attractiveness of the land for investment and investors. Additionally, it stimulates economic development by revitalizing less developed areas and raising their value over time, as well as achieving social balance by integrating populations and reducing tensions and social frictions that may occur in more

expensive areas. Consequently, the price or cost of land in the city varies according to many factors, including its proximity to urban, commercial, or service centers, among other factors. The land cost index when selecting high-rise building sites in Al-Karada is an important indicator, as it provides the opportunity to acquire larger plots at lower costs, facilitating the selection of the best location for high-rise buildings to achieve higher financial returns, especially if residents are attracted by offering high-quality services and facilities. Thus,

selecting low-cost land appears to be an attractive investment, but it also needs to be considered with land in close vicinity to critical facilities and future growth expectations to ensure that the project is successful and sustainable. So the land areas in which the land cost is less were rated as 10, and areas of high land cost were given the lowest rating of 2, due to which, as seen in Figure 11, the land areas of low cost got the highest rating.

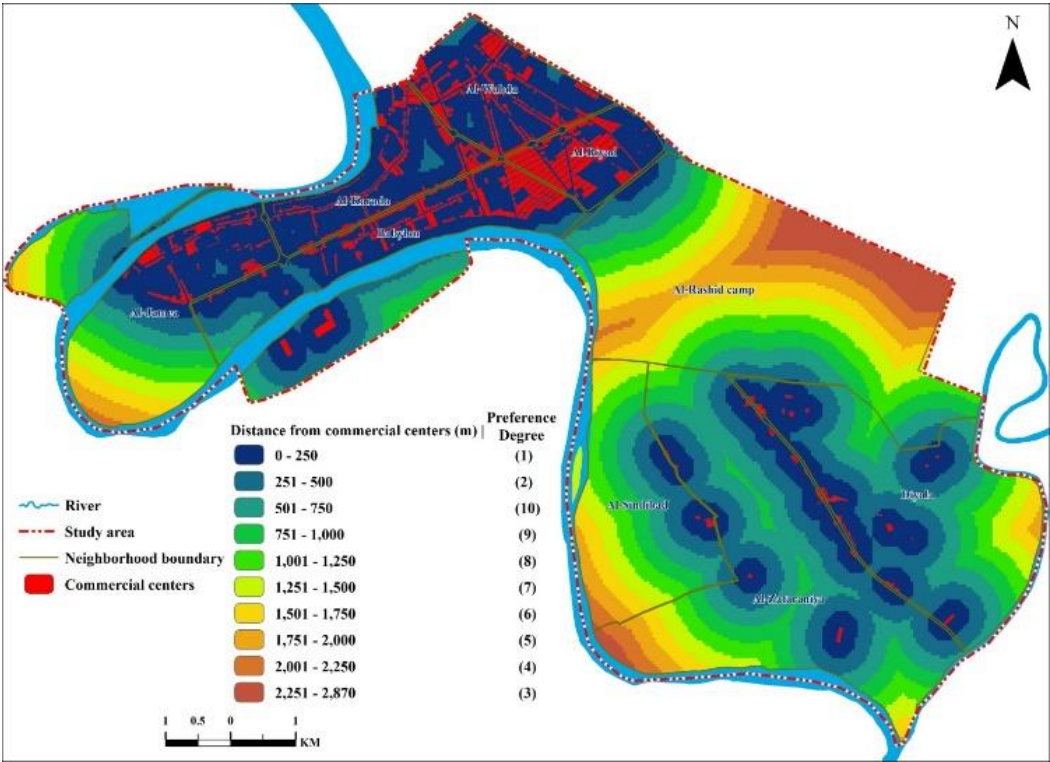


Figure 10. Distance from existing commercial centers in Karrada District

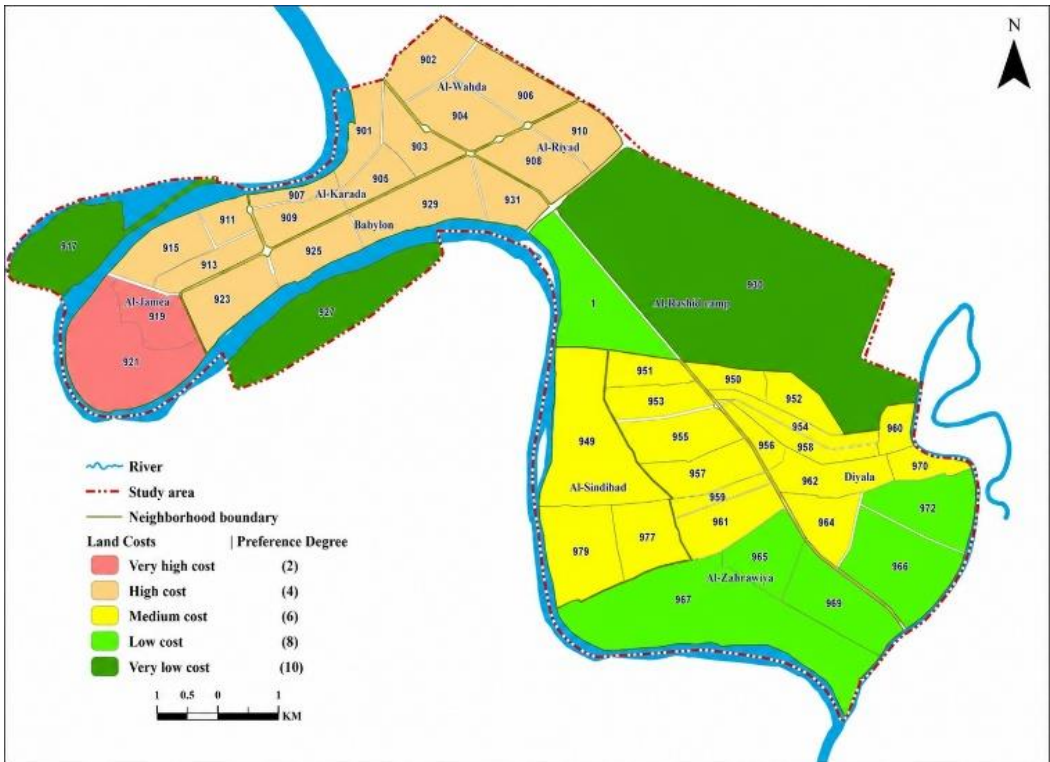


Figure 11. Distance from high-cost land in the Karrada District

4.4 Physical factors

4.4.1 Proximity to main transportation routes

When establishing new business districts and their high-rise buildings, the proximity of high-rise buildings to main traffic routes is a key criterion that attracts people to dwell in the blocks of these high-rise buildings. Al-Karada is considered an important commercial center in Baghdad, making it an appealing destination for both residents and workers. The area boasts a network of highways totaling 16.89 km and main roads measuring 102.14 km, while a series of secondary roads, extending 112.9 km, connect it to other parts of the region. Consequently, the presence of these high-rise buildings near major and express roads can provide these structures with

advantages and the potential for further development and the construction of additional high-rise buildings or even skyscrapers, should space allow. Based on this, the study area has been divided using the Euclidean Distance tool. The areas closest to the transportation routes are the best for constructing high-rise buildings, given that these buildings are generators of movement with a high population density, which requires the presence of close and faster transportation routes to improve the quality of jobs and enhance the ease of access for users to their various destinations. The suitability of places for these buildings decreases the further we move away from them, as the closest has a higher score of 10 and gradually decreases to 1 the further we move away within the boundaries of the area, as illustrated in Figure 12.

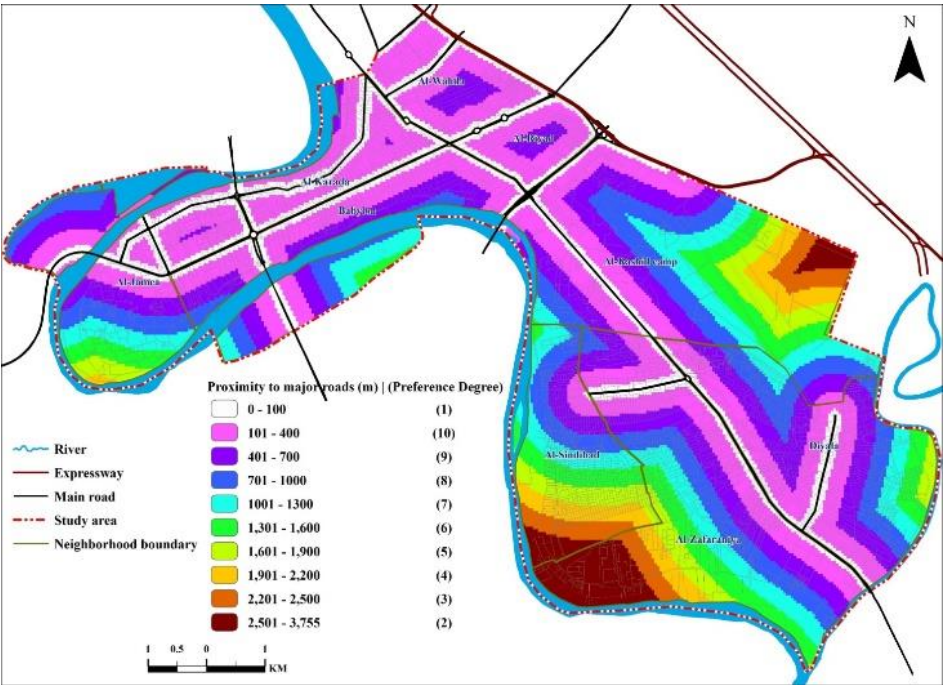


Figure 12. Proximity to main transportation routes

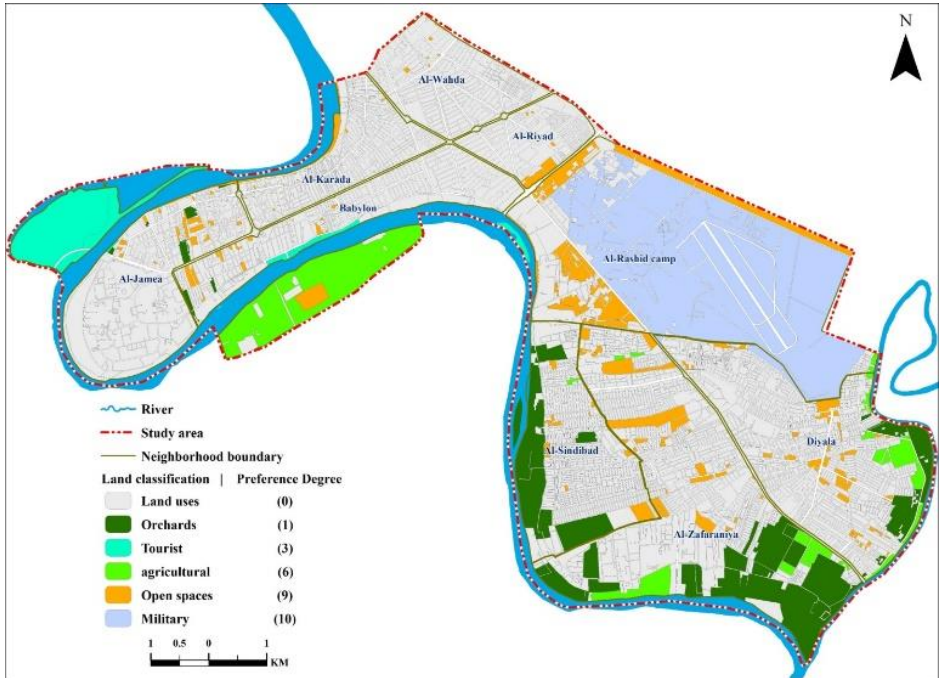


Figure 13. Proximity to types of land suitable for construction

4.4.2 Proximity to undeveloped and buildable land

Lands with low costs are a significant indicator in the allocation of high-rise buildings due to the ease of acquiring and building on such land. Relying on undeveloped areas or vacant land will facilitate the acquisition process, encourage investment, and investors, and reduce community opposition in the study area to the establishment of high-rise projects. Additionally, it stimulates economic development by revitalizing less-developed areas and increasing their value over time, as well as improving infrastructure and public services in the region. Furthermore, it achieves social balance by integrating residents and reducing social tensions and conflicts. Consequently, land uses in the study area have been divided into several sections, identifying the areas where high-rise buildings can be constructed, which consist of open land without built structures. These areas include military zones, open spaces, orchards, agricultural lands, and tourist regions. The undeveloped land criterion in this study indicates the availability of unbuilt areas that could represent initial opportunities for spatial investigation, and does not imply that all open land is actually developable. Certain uses, such as military land, protected areas, orchards, agricultural land, heritage sites, or legally restricted areas, may be subject to restrictions that prevent or limit development regardless of the calculated spatial suitability score. Therefore, this criterion should be interpreted as an indicator of land availability from a preliminary spatial perspective, with sites scoring higher subsequently subject to verification of ownership, legal status,

and regulatory restrictions before being considered developable land. When high-rise buildings are constructed near these uses, they provide an environment and an aesthetic view for these structures (Figure 13).

4.5 Generating the final spatial suitability map

After outlining the impact of the various factors and indicators influencing the selection of the best site for high-rise buildings or skyscrapers in the study area, the spatial suitability for selecting locations for tall buildings in Al-Karada City will be evaluated using ArcGIS 10.8, according to the relative importance assigned to each indicator in Table 7. Based on the justifications provided for each factor regarding its significance during the classification process, seven layers of criteria have been introduced. A reclassification of each layer was conducted using the Reclassify tool under the relative importance within the indicator framework. These layers were overlaid and matched within the GIS environment, utilizing the Spatial Analyst applications, with a weight assigned to each criterion based on its relative importance through the Raster Calculator tool. Consequently, this process produced the spatial suitability classification for high-rise development for high-rise buildings in the study area, as illustrated in Figure 14. The study area has been categorized into five classes, ranging from very low to very high suitability, as detailed in Table 8, along with the categories, classifications, and their respective areas.

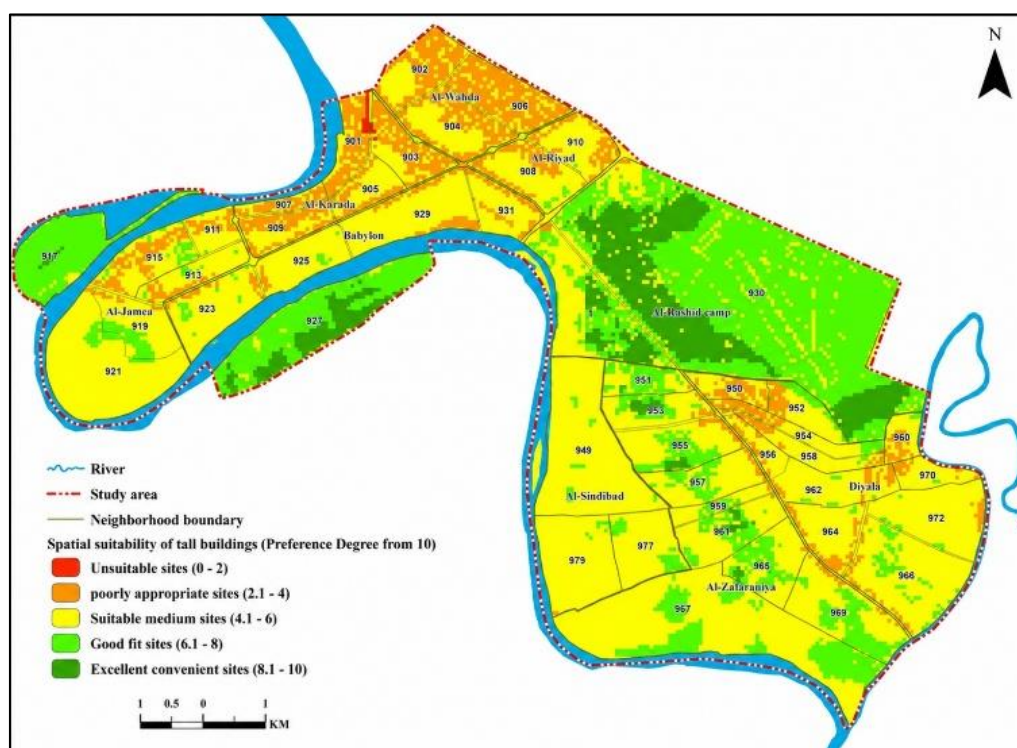


Figure 14. Spatial suitability of the locations of high-rise buildings in the Karrada area

Table 10. Spatial suitability for high-rise building locations

No.	Spatial Suitability of Tall Buildings	Preference Degree from (10)	Area (ha)	%
1	Unsuitable sites	(0–2)	10.25	0.14
2	Poorly appropriate sites	(2.1–4)	731.79	9.82
3	Suitable medium sites	(4.1–6)	4,499.29	60.35
4	Good fit sites	(6.1–8)	1,707.26	22.9
5	Excellent convenient sites	(8.1–10)	506.13	6.79
	SUM		7,454.72	100

The results of the spatial analysis showed that the excellent and good suitability locations are concentrated in sectors 1 and 930 within the Al-Rasheed Camp, sector 917 within the Al-Jamea neighborhood, and sector 927 within the Babylon neighborhood, in addition to their presence in other sectors. The areas classified as excellent and good total 506.13 and 1,707.26 hectares, respectively, summing up to a total area of 2,213.39 hectares, which constitutes approximately 29.69% of the study area. On the other hand, the remaining categories are less significant in terms of the potential for high-rise building placement, collectively covering an area of 5,241.33 hectares, representing 70.31% of the study area. Consequently, the optimal locations for selecting high-rise buildings are determined based on the most suitable sites to achieve the best distribution and future development. The very high suitability class covers 506.13 hectares and represents the highest-priority areas for further detailed planning assessment (Table 10).

4.6 Expert-based validation results

The independent expert validation indicated a high overall level of agreement regarding the planning and spatial plausibility of the suitability model outputs. The overall mean score across the eight validation items was 4.28 out of 5, indicating a very high level of agreement among the experts regarding the general plausibility of the model results. The detailed validation results are presented in Table 11 (raw expert ratings are provided in Table A4).

Table 11. Results of the independent expert validation

Validation Item	Mean	Standard Deviation	Interpretation
V1	4.40	0.55	Very High
V2	4.20	0.45	High
V3	4.80	0.45	Very High
V4	4.40	0.55	Very High
V5	4.20	0.45	High
V6	3.60	0.55	High
V7	4.40	0.55	Very High
V8	4.20	0.84	High
Overall	4.28	0.60	Very High

Among the eight validation items, V3 recorded the highest mean score (4.80), indicating very high expert agreement regarding the plausibility of identifying parts of Rashid Camp and neighborhoods 917 and 927 within the higher suitability classes as an initial spatial-screening result. Items V1, V4, and V7 also received very high ratings, with mean scores of 4.40, reflecting strong agreement regarding the overall spatial distribution of suitability classes, the consistency of the results with accessibility and major transportation routes, and the usefulness of the five suitability classes for prioritizing areas for further detailed planning studies. In contrast, V6 had the lowest mean score (3.60), but was still in the high-agreement range, suggesting a relatively higher level of expert uncertainty about representation of spatial conditions at the strategic screening level in terms of natural, historical and hazard aspects.

5. DISCUSSION

The interrelationships between the seven criteria were discussed taking into consideration the nature of the Karrada

District and the level of optimal development site selection that can be supported by the proposed spatial framework in dense urban areas. The suitability map should not be read as an absolute map of buildable plots, but rather a tool for a strategic spatial analysis that helps to focus the analysis and pinpoint areas that warrant further analysis. It can support the selection of high-value development sites within dense urban areas.

5.1 Significance of spatial variation in suitability levels

The results showed that spatial suitability for high-rise development was not uniformly distributed within the Karrada District, but rather resulted from the complex interaction of the studied criteria. This variation shows that individual criteria, such as being close to main roads and low land value, can be limiting factors in determining where high-rise buildings are located.

Therefore, the largest area in the study was almost occupied by the medium suitability category with 4,499.29 ha or 60.35% of the total area of the study. This category dominates for Karrada, which is intentional, to some extent causing it to lose out on a large share of the aspirations of a high-rise development, but it also doesn't have all the preferred qualities to the extent needed to qualify it as a top priority. While they may be located near transportation or away from certain hazards, one or more of these sites may be subject to high land value, high population density, and/or limited availability of undeveloped land.

Sites that qualified for high suitability, on the other hand, amounted to 1,707.26 hectares or 22.90% of the total area, and very high suitability sites amounted to 506.13 hectares or 6.79%. The total area of these two zones was 2,213.39 ha, accounting for about 29.69% of the study area. The percentage reflects an important spatial bottom and allows for future vertical growth studies. Not all of this area is necessarily available for building projects, however, as some of these pieces of land may have existing uses and others may be unavailable for site development or in need of detailed examination of the capacity of the water, sewage, energy, and transportation systems.

The low and very low sites totaled 742.04 ha or ~9.96% of the study area. Most of Karrada is not absolutely spatially constrained: the percentages of these categories are lower than others, indicating this. But this does not preclude the presence of sensitive areas in which development is not recommended because it places the development at high risk, for example, areas close to natural and historic features, areas impacted by hazards, areas with limited accessibility and/or land availability.

This discovery supports the need to adopt a hierarchical approach, instead of sorting into just two categories: suitable and unsuitable locations. This realistic planning in built-up areas is not necessarily land free of all constraints, but rather a selection of various levels of suitability and then an action plan to fill all the gaps in each. This means that the medium category may be considered to be a conditional planning reserve, and high and very high categories as the primary planning areas for study detail.

5.2 Interpreting the relative importance of the criteria

Through the use of AHP, the characteristics of proximity to undeveloped and buildable areas were found to be the top one, followed by a weight of 20%. This is because the availability

of land is a necessary condition for a feasibility study in the development of high-rise buildings; for instance, in areas where high buildings overlap and where land is already utilized, the demolition and redevelopment expenses are very high. If a site has good accessibility or is near some of the services, but there is not a suitable plot on the site, then development can become more complex, and it can be less viable. The focus on undeveloped land does not imply that development can be encouraged at the cost of agricultural land, orchards and/or environmentally sensitive places, as these are accounted for in a separate criterion which impacts the suitability of nearby sites. This reveals the balance the model attempted to achieve between ease of development on the one hand and the protection of natural and historical resources on the other. This distinction is particularly important in the study area because of the presence of military, environmental, and heritage uses that may appear spatially as undeveloped land, but cannot automatically be considered land available for development. Therefore, the high degree of suitability in the model does not negate the need for subsequent verification of the land's legal and regulatory status. The criterion of avoiding high-value land ranked second, with a weight of 16%. This weight reflects the importance of economic feasibility in selecting sites for high-value projects, as high land prices increase the initial project cost and may lead developers to excessively increase building density to offset acquisition costs. However, the preference for lower-value land does not necessarily mean choosing peripheral or isolated locations. The criterion of proximity to major transportation routes counteracts this trend and ensures that proposed sites are connected to the urban transportation network. The criterion of proximity to low-density areas ranked third, with a weight of 15%. This is due to the desire to ensure that no added urban stresses are imposed on neighborhoods already under strain and that are already highly built. Low density should not be the only measure of capacity, though—some low density areas might be lacking in infrastructure, or services are hard to reach. Creating networks and infrastructure to support this development, then, calls for checking population density—along with the actual capacity of networks already on the books. Distance from seismic activity zones was weighted at 14%, and this is important because, in the design of high-rise buildings, it is very important to have safe building directions, as the loads, foundation requirements, and sensitivity to ground movements differ from those of conventional buildings. The criterion, however, is a general spatial assessment and is not intended to be a substitute for detailed site-level geotechnical and seismic studies; the suitability of a proposed plot will also be influenced by the type of soil, the depth of the water table, the bearing capacity, and the foundation system to be adopted. The proximity to main transportation routes was given a weight of 13%, as accessibility and connectivity to the rest of the city was an important factor. Proximity to major thoroughfares can enhance accessibility, and these are likely to have a higher level of trips for high-rise buildings, whether residential or commercial or a hybrid of both. But being close to a road doesn't necessarily mean there is adequate traffic volume; however, if the sites are not provided with public transportation, adequate access points, good design of parking facilities, and a comprehensive traffic impact analysis, high-rise development can have a negative impact on traffic. Distance from the already existing commercial centers was weighted at 12%. This is because people want to alleviate the

lack of balance in the distribution of activities in current centers, and promote the development of new clusters. However, excessive distance can result in poor connections to activities and services. Hence, centers should not be encouraged to be located away from the urban fabric through this criterion, but rather as a way to support a balanced distribution of centers. Distance from natural and historical sites received the lowest weight, at 10%. This does not imply that these sites are unimportant, but rather that their relative weight was lower compared to other operational and economic criteria within the decision model. Peaceful preservation of orchards, areas of agriculture, banks of the Tigris River, and areas of heritage are fundamental requirements. Some elements, such as protected areas, riverbanks, heritage sites, and legally restricted lands, may be best treated in subsequent studies as non-compensable exclusionary constraints, rather than allowing their lower suitability to be compensated for by high scores in other criteria. Looking at the ranking of criteria overall, it seems that experts gave due consideration to the density, safety and accessibility criteria and that spatial and economic considerations (land availability and value) were considered more important. This approach endows the model with a practical feel and, at the same time, allows for the weights not to be seen as fixed values which apply to all cities—priorities may shift in other cities based on the extent of natural hazards, land availability, mode of transport, planning restrictions, etc.

5.3 Weight robustness and ranking stability

To evaluate the stability of criterion priorities under the $\pm 20\%$ weight perturbation scenarios described in Section 3.7, Spearman's rank correlation coefficient was calculated for each scenario relative to the baseline ranking (Table 12).

Table 12. Spearman rank correlation results for weight-robustness scenarios

Sce. No.	Weight Change	Spearman's ρ	Main Ranking Change
Base.	No change	1.000	C7 > C5 > C3 > C2 > C6 > C4 > C1
1	C1 +20%	0.964	C1 moves from 7th to 6th
2	C1 -20%	1.000	No ranking change
3	C2 +20%	0.893	C2 moves from 4th to 2nd
4	C2 -20%	0.893	C2 moves from 4th to 6th
5	C3 +20%	0.964	C3 moves from 3rd to 2nd
6	C3 -20%	0.786	C3 moves from 3rd to 6th
7	C4 +20%	0.893	C4 moves from 6th to 4th
8	C4 -20%	0.964	C4 moves from 6th to 7th
9	C5 +20%	1.000	No ranking change
10	C5 -20%	0.786	C5 moves from 2nd to 5th
11	C6 +20%	0.786	C6 moves from 5th to 2nd
12	C6 -20%	0.964	C6 moves from 5th to 6th
13	C7 +20%	1.000	No ranking change
14	C7 -20%	0.964	C7 moves from 1st to 2nd

The 14 scenarios were calculated based on the baseline weights in Table A1, where $C1 = 10$, $C2 = 14$, $C3 = 15$, $C4 = 12$, $C5 = 16$, $C6 = 13$, $C7 = 20$.

Therefore, the baseline order is: $C7 > C5 > C3 > C2 > C6 > C4 > C1$ (Table 12).

Weight robustness analysis revealed a high level of stability in the ranking of criteria across the fourteen scenarios. Spearman's correlation coefficients ranged from 0.786 to 1.000, with a mean of 0.918 and a median of 0.964. Criterion $C7$ maintained its first ranking in thirteen out of fourteen scenarios and only moved to second place when its weight was reduced by 20%. The largest relative changes in ranking occurred when the weight of $C3$ was reduced, the weight of $C5$ was reduced, and the weight of $C6$ was increased, although the correlation coefficients remained relatively high. These results indicate the robustness of the weighting structure and the stability of the overall priority of the criteria within the assumed range of change, and do not represent a test of the stability of the spatial distribution of the suitability categories.

The modified weights for all 14 scenarios are presented in Table A1, while Table A2 provides an illustrative calculation of Spearman's rank correlation coefficient for the $C1 + 20\%$ scenario.

5.4 Interpreting the spatial concentration of highly suitable areas

The very highly suitable areas were mainly concentrated in parts of Camp Rashid, District 917, which is in the University Sector, and District 927, which is in the Babylon Sector. This concentration is attributed to the alignment of various amenities to these locations, such as the presence of developable land, the relatively low land value or population density, and the potential to be connected to a network of transportation infrastructure or certain natural and historic traits which, when compared to other places, are relatively distant. The outer location of the proposed sites (where the traditional demand-to-congestion ratio estimates that there are fewer congestion problems) suggests that the model is not capturing the concentration pattern of existing sites but rather has a tendency to trigger growth opportunities in locations that are farther out from the main commercial hub to enable secondary centers or new hubs to develop. This can lead to a shift of activities and population away from the center and lessen the strain on the central areas if it is supported by the availability of services, public transport, and links with existing urban fabric. The inclusion of parts of Camp Rashid in the high suitability categories requires careful interpretation. The result reflects the spatial characteristics introduced by the model and does not imply that the land is legally or practically available for development. While the availability of undeveloped land may have contributed to the higher ranking of some sites, military or security status, land ownership, potential for change of use, possible prior contamination, and the capacity of networks and services are subsequent validation factors that must be examined before moving from spatial suitability to development viability. Therefore, these sites should be treated as opportunities for strategic screening only, not as sites approved for construction. The same applies to neighborhoods 917 and 927; a high spatial analysis suitability is not necessarily an indication of the type of development, building height, or density. Detailed plot-level analysis is suggested for sites in these communities that will consider road width, size of plot, building ratios, setbacks,

shading and wind conditions, service capacity, and existing residential uses. These results suggest that instead of random placement of high-rise towers in Karrada, development should be in an area where infrastructure, communities, public spaces, services, and transportation are part of the development. By doing so, it helps to reduce some of the negative impacts associated with the development of high-rise buildings in low-rise residential neighborhoods if these issues are not addressed—specifically elevation, density, and visual and social privacy transitions.

5.5 Study limitations and site-level verification requirements

The study results should be interpreted in light of the model's scope and the level of data used. The framework was designed to identify relative variances in suitability across the study area, not to provide a definitive engineering or regulatory assessment for each plot. Therefore, the seven criteria used do not cover all the determinants required for actual high-rise project approval. Requirements to be examined at a later stage include soil geotechnical properties, groundwater depth, flood risk, flight height restrictions, water, sewage, and energy network capacities, traffic capacity and availability of public transport, fire and emergency vehicle access, plot geometry and ownership, land use regulations, building ratios, floor area factor, and the effects of wind, shading, and privacy on buildings and surrounding areas. The categories that are derived, thus, are priorities for further study and detailed evaluation, and not actual permits for development.

5.6 Interpretation of the independent expert validation

Plausible planning of the model outputs is supported by the independent expert validation with an overall mean score of 4.28 out of 5. This shows that the spatial distribution of the suitability classes and identification of priority areas were in general consistent with the professional assessment of the five independent experts. The following agreement should be viewed in the context of an agreement for the use of the model as a strategic spatial-screening tool, however, and not as proof of the legal, engineering, or construction feasibility of individual plots.

The means for the highest-rated validation items, V3 (4.80) and V4 (4.40), were in the very high category, suggesting that there was high expert consensus for the plausibility of the items identified as parts of Rashid Camp and neighborhoods 917 and 927, respectively, as an initial spatial-screening result in the higher suitability classes. This result is significant as these areas were the main areas of very high suitability in the spatial analysis. However, the expert support for their spatial plausibility does not mean that these areas are necessarily available and/or legally appropriate for development. In particular, the interpretation of Rashid Camp remains subject to land ownership, military and security uses, regulatory restrictions, and other site-level constraints that were not incorporated as exclusionary layers in the current model.

Item V6 received the lowest mean score (3.60), although it remained within the high-agreement category. This relatively lower rating suggests greater expert caution regarding the extent to which natural, historical, and hazard-related spatial conditions are represented within the current strategic screening framework. This finding is consistent with the

defined scope of the model, which does not incorporate all environmental, legal, and site-specific constraints as non-compensatory exclusion layers. Therefore, the lower score for V6 should not be interpreted as a rejection of the model outputs, but rather as an indication that environmentally sensitive and hazard-related conditions require additional verification before moving from strategic spatial suitability to site-level development decisions.

Taken together, the validation results provide additional support for the use of the proposed framework as a strategic spatial-screening tool while also reinforcing the need for detailed environmental, legal, infrastructural, and site-specific assessments before any development decision is made.

6. CONCLUSION

The need for high-rise buildings in the urban area is apparent in their ability to concentrate people density from horizontal (spatial) living to vertical living, which is important in fast-growing cities with increasing land costs, as in the case of Baghdad city in general and specifically the Karrada area. Leveraging vertical space can reduce the cost of land, while also offering a variety of services and facilities (shopping centers, sports clubs, recreational, health and community facilities) that can draw in people looking for a modern, comfortable lifestyle.

The suitability results indicate that areas with better access to major transportation routes, lower land-value constraints, and greater availability of developable land tend to receive higher suitability scores. These areas may therefore represent potential locations for further detailed assessment of high-rise development. However, the model does not directly evaluate subsequent economic, social, traffic, or infrastructure impacts, and such outcomes should be assessed through additional site-specific studies before implementation.

Based on many spatial indicators, suitable areas for the establishment of high-rise buildings within the study area were identified using ArcGIS 10.8. By applying these indicators, areas with different levels of suitability were identified according to the spatial planning criteria incorporated in the model, including proximity to low population density, closeness to major transportation routes, distance from commercial centers, proximity to types of land suitable for construction, distance from natural and archaeological sites, distance from seismic activity zones, distance from high-cost lands, etc. The results of the spatial survey showed that parts of Rashid Camp, along with neighborhoods 917 and 927, fall within the highest categories of suitability according to the criteria used. However, these results do not necessarily mean that the land is available for development, particularly in military or restricted areas, as any subsequent decision will require verification of ownership, legal and regulatory restrictions, and infrastructure.

The independent expert validation further supported the spatial plausibility and planning of the model outputs that had a mean score of 4.28 out of 5, which validates the use of the framework as a strategic spatial-screening tool and not a replacement for site-level assessment.

REFERENCES

- [1] Dave, S. (2010). High urban densities in developing countries: A sustainable solution? *Built Environment*, 36(1): 9-27. <https://doi.org/10.2148/benv.36.1.9>
- [2] Awuah, K.G.B., Abdulai, R.T. (2022). Urban land and development management in a challenged developing world: An overview of new reflections. *Land*, 11(1): 129. <https://doi.org/10.3390/land11010129>
- [3] Al-Kodmany, K. (2018). Sustainability and the 21st century vertical city: A review of design approaches of tall buildings. *Buildings*, 8(8): 102. <https://doi.org/10.3390/buildings8080102>
- [4] Al-Jawari, S.M., Al-Mosawy, S.K., Al-Jaberi, A.A., Al-Baghdadi, A.N. (2020). Strategic analysis of new cities (Case study Basmaya city - Republic of Iraq) An analytical study of strength, weakness, opportunity, and threat. *IOP Conference Series: Earth and Environmental Science*, 459(6): 062108. <https://doi.org/10.1088/1755-1315/459/6/062108>
- [5] Sayigh, A. (2017). Sustainable High Rise Buildings in Urban Zones: Advantages, Challenges, and Global Case Studies. Springer. <https://doi.org/10.1007/978-3-319-17756-4>
- [6] Aduwo, E.B., Sholanke, A.B., Eleagu, J.C. (2024). Prospects, challenges and solutions for achieving sustainability in implementing green architecture strategies in high-rise buildings: A review. *IOP Conference Series: Earth and Environmental Science*, 1428(1): 012004. <https://doi.org/10.1088/1755-1315/1428/1/012004>
- [7] Ali, M.M., Al-Kodmany, K. (2012). Tall buildings and urban habitat of the 21st century: A global perspective. *Buildings*, 2(4): 384-423. <https://doi.org/10.3390/buildings2040384>
- [8] Al-Mosawy, S.K.A., Al-Jawari, S.M., Al-Jabari, A.A. (2020). The effect of urban form on temperature for hot arid zones. The case study of Baghdad, Iraq. *IOP Conference Series: Earth and Environmental Science*, 459(6): 062109. <https://doi.org/10.1088/1755-1315/459/6/062109>
- [9] Tamošaitienė, J., Šipalis, J., Banaitis, A., Gaudutis, E. (2013). Complex model for the assessment of the location of high-rise buildings in the city urban structure. *International Journal of Strategic Property Management*, 17(1): 93-109. <https://doi.org/10.3846/1648715X.2013.781968>
- [10] Ptušina, I., Spiridonova, T., Musorina, T.A. (2015). Performance evaluation of high-rise complex construction depending on building site placement. *Applied Mechanics and Materials*, 725-726: 153-159. <https://doi.org/10.4028/www.scientific.net/AMM.725-726.153>
- [11] Abdulameer, H.N., Al-Jaberi, A.A., Al-Khafaji, A.S., Alrobaee, T.R., Al-Ansari, H.A. (2024). Evaluating of urban space vitality: The role of safety, security, and urban planning in the religion center of Kufa City, Iraq. *International Journal of Design and Nature and Ecodynamics*, 19(1): 155-167. <https://doi.org/10.18280/ij dne.190118>
- [12] Abdulhamza, E.S., Al-Jaberi, A.A. (2025). Trends in spatial justice in urban space planning: A study of selected urban spaces in 1st Kinda neighborhood in the city of Kufa-Iraq. *International Journal of Sustainable Development and Planning*, 20(6): 2519-2531. <https://doi.org/10.18280/ij sdp.200620>
- [13] Tugrul Okbaz, F. (2025). Evaluation of space efficiency

- criteria in high-rise buildings based on functions: A case study of Türkiye. *Architectural Engineering and Design Management*, 21(1): 60-77. <https://doi.org/10.1080/17452007.2024.2404115>
- [14] Yang, F., Chen, L. (2020). *High-Rise Urban Form and Microclimate: Climate-Responsive Design for Asian Mega-Cities*. Springer Nature. <https://doi.org/10.1007/978-981-15-1714-3>
- [15] Wang, H., Shen, Q., Tang, B.S., Lu, C., Peng, Y., Tang, L. (2014). A framework of decision-making factors and supporting information for facilitating sustainable site planning in urban renewal projects. *Cities*, 40: 44-55. <https://doi.org/10.1016/j.cities.2014.04.005>
- [16] Tamošaitienė, J., Gaudutis, E., Kračka, M. (2013). Integrated model for assessment of high-rise building locations. *Procedia Engineering*, 57: 1151-1155. <https://doi.org/10.1016/j.proeng.2013.04.145>
- [17] Paszkowski, Z.W., Czyńska, K., Paszkowska-Kaczmarek, N.E. (2025). The role of tall buildings in sustainable urban composition—The case of Hanza Tower in Szczecin (Poland). *Arts*, 14(2): 30. <https://doi.org/10.3390/arts14020030>
- [18] Utami, C., Septiningtyas, D., Debataraja, L.R., Oktaviani, T., Zulkarnain, F. (2024). Mapping the distribution of high buildings in West Medan subdistrict using geographic information system (GIS). *Jurnal Inotera*, 9(2): 536-543. <https://doi.org/10.31572/inotera.Vol9.Iss2.2024.ID426>
- [19] Weng, C., Zhuang, Y. (2023). Evolution of skyscraper block typology affected by air rights development: A case study of Manhattan. *International Journal of High-Rise Buildings*, 12(1): 19-33. <https://doi.org/10.21022/IJHRB.2023.12.1.19>
- [20] Mohamed, N.M., Bashandy, S.Y., El-Barmelgy, H.M., Al-Attar, A.F. (2022). Spatial analysis model for allocation of high-rise building. *Civil Engineering and Architecture*, 10(5A): 1-32. <https://doi.org/10.13189/cea.2022.101401>
- [21] Munn, K., Dragičević, S. (2021). Spatial multi-criteria evaluation in 3D context: Suitability analysis of urban vertical development. *Cartography and Geographic Information Science*, 48(2): 105-123. <https://doi.org/10.1080/15230406.2020.1845981>
- [22] Mansouri Daneshvar, M.R., Khatami, F., Shirvani, S. (2017). GIS-based land suitability evaluation for building height construction using an analytical process in the Mashhad city, NE Iran. *Modeling Earth Systems and Environment*, 3(1): 16. <https://doi.org/10.1007/s40808-017-0286-z>
- [23] Al-Jaberi, A.A., Al-Khafaji, A.S.A., Al-Salam, N.A., Alrobaee, T.R. (2021). The crossing as a new approach for the urban transformation of traditional cities towards the sustainability. *International Journal of Sustainable Development and Planning*, 16(6): 1049-1059. <https://doi.org/10.18280/ijstdp.160606>
- [24] Ahmed, M., Ashour, A. (2023). The effect of architectural landmarks on a skyline and the mental images of the cities of ancient civilizations. *AIP Conference Proceedings*, 2651(1): 020067. <https://doi.org/10.1063/5.0106893>
- [25] Leiermann, T. (2021). Rehabilitation of historic Shibam and Zabid, Yemen as an impulse for community and economy. *Built Heritage*, 5(1): 20. <https://doi.org/10.1186/s43238-021-00044-8>
- [26] Al-Kodmany, K. (2023). Elevator technology improvements: A snapshot. *Encyclopedia*, 3(2): 530-548. <https://doi.org/10.3390/encyclopedia3020038>
- [27] Flowers, B. (2009). *Skyscraper: The Politics and Power of Building New York City in the Twentieth Century*. University of Pennsylvania Press.
- [28] Asabere, S.B., Acheampong, R.A., Ashiagbor, G., et al. (2020). Urbanization, land use transformation and spatio-environmental impacts: Analyses of trends and implications in major metropolitan regions of Ghana. *Land Use Policy*, 96: 104707. <https://doi.org/10.1016/j.landusepol.2020.104707>
- [29] Jasim, I.A., Al-Jaberi, A.A., Al-Maliki, L.A., Al-Ansari, N., Al-Mamoori, S.K. (2022). Do the population density and coverage rate of transit affect the public transport contribution? *Cogent Engineering*, 9(1): 2143059. <https://doi.org/10.1080/23311916.2022.2143059>
- [30] Al-Kodmany, K. (2024). Refashioning cities in the Middle East: The case of Dubai. *International Journal of High-Rise Buildings*, 13(1): 11-32. <https://doi.org/10.21022/IJHRB.2024.13.1.11>
- [31] Al-Ameer, A.S., Al-Mosawy, S.K. (2024). The space formations of the built environment and green areas between Islamic heritage and modernity. *AIP Conference Proceedings*, 3092(1): 060015. <https://doi.org/10.1063/5.0200076>
- [32] Grace Wong, K.M. (2004). Vertical cities as a solution for land scarcity: The tallest public housing development in Singapore. *Urban Design International*, 9(1): 17-30. <https://doi.org/10.1057/palgrave.udi.9000108>
- [33] Al-Tamimi, A.H., Alnasrawy, A.A.M., Al-Hatmi, M.H., Al-Ansari, N., Al-Mamoori, S.K., Jiddy, Z.A.J. (2022). Urban uses change an analytical study using geographic information systems/Kufa city as a model. *Cogent Engineering*, 9(1): 2143065. <https://doi.org/10.1080/23311916.2022.2143065>
- [34] Narayanaswami, S. (2017). Urban transportation: Innovations in infrastructure planning and development. *The International Journal of Logistics Management*, 28(1): 150-171. <https://doi.org/10.1108/IJLM-08-2015-0135>
- [35] Abuali, A.M., Al-Shaybann, A.A., Buragba, R. (2019). Urban development in the Republic of Iraq. Ecological assessment, development stages. Impact of the planned object on the environment. *IOP Conference Series: Materials Science and Engineering*, 698(3): 033040. <https://doi.org/10.1088/1757-899X/698/3/033040>
- [36] Kong, L. (2007). Cultural icons and urban development in Asia: Economic imperative, national identity, and global city status. *Political Geography*, 26(4): 383-404. <https://doi.org/10.1016/j.polgeo.2006.11.007>
- [37] Generalova, E., Generalov, V. (2020). Mixed-use high-rise buildings: A typology of the future. *IOP Conference Series: Materials Science and Engineering*, 753(2): 022062. <https://doi.org/10.1088/1757-899X/753/2/022062>
- [38] Abkharima, M.H., Perkova, M.V., Al-Jaberi, A.A.H. (2020). World experience in the use of GIS technologies in solving problems of sustainable development of the city. *IOP Conference Series: Materials Science and Engineering*, 753(3): 032045. <https://doi.org/10.1088/1757-899X/753/3/032045>
- [39] Attah, R.U., Gil-Ozoudeh, I., Garba, B., Iwuanyanwu, O. (2024). Leveraging geographic information systems and

- data analytics for enhanced public sector decision-making and urban planning. *Magna Scientia Advanced Research and Reviews*, 12(2): 152-163. <https://doi.org/10.30574/msarr.2024.12.2.0191>
- [40] Tavana, M., Soltanifar, M., Santos-Arteaga, F.J. (2023). Analytical hierarchy process: Revolution and evolution. *Annals of Operations Research*, 326(2): 879-907. <https://doi.org/10.1007/s10479-021-04432-2>
- [41] Chen, Y., Yu, J., Khan, S. (2013). The spatial framework for weight sensitivity analysis in AHP-based multi-criteria decision making. *Environmental Modelling & Software*, 48: 129-140. <https://doi.org/10.1016/j.envsoft.2013.06.010>
- [42] Ali, F., Salman, A. (2024). Spatial assessment and comparison of land use in Karrada City, Iraq, using geographic information systems. *Journal of Engineering*, 30(10): 134-149. <https://doi.org/10.31026/j.eng.2024.10.08>
- [43] Abbas Ahmed, Z., Ebraheem, M.A. (2021). Analysis of the effective change in the functions of land use and its impact on city structure, the study area Karrada/Baghdad/Iraq. *IOP Conference Series: Earth and Environmental Science*, 754(1): 012008. <https://doi.org/10.1088/1755-1315/754/1/012008>
- [44] Kattanh, M.A., Al-Jaberi, A.A., Abd Al-Mosawy, S.K., Al-Khafaji, A.S., Alrobaee, T.R. (2023). Estimating parking demand for commercial areas in Baghdad-Iraq. *International Journal of Sustainable Development and Planning*, 18(12): 3823-3829. <https://doi.org/10.18280/ijstdp.181214>

APPENDIX

Table A1. Modified weights in weight-robustness scenarios

Scenario	Procedures	C1	C2	C3	C4	C5	C6	C7
Calculated	None	10.00	14.00	15.00	12.00	16.00	13.00	20.00
1	Increasing C1	12.00	13.69	14.67	11.73	15.64	12.71	19.56
2	Decreasing C1	8.00	14.31	15.33	12.27	16.36	13.29	20.44
3	Increasing C2	9.67	16.80	14.51	11.61	15.48	12.58	19.35
4	Decreasing C2	10.33	11.20	15.49	12.39	16.52	13.42	20.65
5	Increasing C3	9.65	13.51	18.00	11.58	15.44	12.54	19.29
6	Decreasing C3	10.35	14.49	12.00	12.42	16.56	13.46	20.71
7	Increasing C4	9.73	13.62	14.59	14.40	15.56	12.65	19.45
8	Decreasing C4	10.27	14.38	15.41	9.60	16.44	13.35	20.55
9	Increasing C5	9.62	13.47	14.43	11.54	19.20	12.50	19.24
10	Decreasing C5	10.38	14.53	15.57	12.46	12.80	13.50	20.76
11	Increasing C6	9.70	13.58	14.55	11.64	15.52	15.60	19.40
12	Decreasing C6	10.30	14.42	15.45	12.36	16.48	10.40	20.60
13	Increasing C7	9.50	13.30	14.25	11.40	15.20	12.35	24.00
14	Decreasing C7	10.50	14.70	15.75	12.60	16.80	13.65	16.00

Table A2. Model for calculating Spearman's correlation coefficient for the scenario of increasing weight C1

Criteria	Basic Weight	Basic Rank	Modified Weight	Modified Rank	Ranks Difference d_i	d_i^2
C1	10.00	7	12.00	6	1	1
C2	14.00	4	13.69	4	0	0
C3	15.00	3	14.67	3	0	0
C4	12.00	6	11.73	7	-1	1
C5	16.00	2	15.64	2	0	0
C6	13.00	5	12.71	5	0	0
C7	20.00	1	19.56	1	0	0
Total	100	—	100	—	—	2

Table A3. Independent expert validation questionnaire

The purpose of this questionnaire is to evaluate the planning and spatial feasibility of the results of the site suitability assessment model for high-rise development in the Karrada area. Please assess the final map and the five suitability categories from your professional experience. The results should be used as a tool for strategic spatial screening and not as an endorsement of development or construction.										
Score	Interpretation									
1	Very Low Agreement									
2	Low Agreement									
3	Moderate Agreement									
4	High Agreement									
5	Very High Agreement									
Code	Validation Statement					1	2	3	4	5
V1	The overall spatial distribution of the five suitability classes is reasonable within Karrada District.					☐	☐	☐	☐	☐
V2	The areas classified as High and Very High suitability are generally consistent with the known planning characteristics of the study area.					☐	☐	☐	☐	☐
V3	The occurrence of parts of Rashid Camp and neighborhoods 917 and 927 within the higher suitability classes is reasonable as an initial spatial-screening result.					☐	☐	☐	☐	☐

V4	The spatial suitability results are reasonably consistent with accessibility and the distribution of major transportation routes.	☐	☐	☐	☐	☐
V5	The results reasonably reflect variations in population density, land value, and availability of undeveloped/buildable land.	☐	☐	☐	☐	☐
V6	The suitability pattern reasonably reflects the consideration of natural, historical, and hazard-related spatial conditions at the strategic screening level.	☐	☐	☐	☐	☐
V7	The five suitability classes provide a reasonable basis for prioritizing areas that require further detailed planning investigation.	☐	☐	☐	☐	☐
V8	The final suitability map is useful as a strategic spatial-screening tool for guiding preliminary high-rise development planning in Karrada District.	☐	☐	☐	☐	☐
V9	Please identify any suitability result or location that you consider inconsistent with your professional assessment and briefly explain the reason.					

Table A4. Response to the questionnaire of independent expert validation

Experts	V1	V2	V3	V4	V5	V6	V7	V8
E1	4	4	5	4	5	4	5	4
E2	5	5	5	4	4	4	4	3
E3	4	4	5	5	4	3	4	5
E4	4	4	4	4	4	3	4	5
E5	5	4	5	5	4	4	5	4