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Evaluating the feasibility of constructing shopping centers on urban vacant land through a spatial multi-criteria decision-making model

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Shopping centers are among the major economic and commercial places in cities in terms of social function, urban sustainability, environment, etc. Therefore, it is crucial to determine suitable locations for building new shopping centers. In this regard, urban vacant lands can be considered as high-potential locations to transform the urban landscape and enhance socio-economic development. The main purpose of this study is to assess the potential of urban vacant lands based on a spatial multi-criteria decision-making (SMCDM) system for building shopping centers in 22 districts of Tehran. In this study, first, 16 effective spatial criteria for locating the new shopping centers were identified using expert opinions and a literature review. The best-worst method (BWM) and the Min/Max method were used to calculate the weight and standardized values of each criterion. Then, the ordered weighted averaging (OWA) method was used to prepare a potential map of urban vacant lands for the construction of a shopping center under different decision-making scenarios, including very optimistic, optimistic, intermediate, pessimistic, and very pessimistic. Finally, the spatial distribution of potential locations in the 22 districts of Tehran was investigated. The results showed that among the different criteria, the distance from the highway networks and distance from public transportation stations had the most weight, whereas the distance from fault and distance from stream networks had the least weight. The number of vacant lands with a very high potential for building a shopping center in Tehran based on very pessimistic, pessimistic, intermediate, optimistic and very optimistic scenarios was obtained at 29, 95, 105, 122, and 224, respectively. An increase in the degree of optimism in the attitude of decision-makers or investors increased the number of available options in the very high potential category. Under all scenarios, all vacant lands in 10 of Tehran's 22 districts with very high potential for building shopping centers. The results of the proposed model in this study can be useful and practical for a wide range of planners, decision-makers, and investors with different mental attitudes and risk tolerance. Close attention to these results can contribute to achieving sustainable urban development.

KEYWORDS
potential, vacant lands, shopping centers, GIS-SMCDM, Tehran metropolis

1 Introduction

In today's world, cities are rapidly changing and evolving due to the constant population growth and diverse social and economic needs (Nadizadeh Shorabeh et al., 2020; Mansourihanis et al., 2023). One driving force behind these changes is the creation and development of shopping centers as major economic and social hubs (Burayidi and Yoo, 2021). The increase in demand for services and goods has highlighted the need for shopping centers that can handle the ever-increasing population as an urban development priority (Arif et al., 2021). Also, easy access to facilities and infrastructure is one of the priorities in order to achieve a smart city. However, creating suitable shopping centers in cities faces many challenges. One such challenge is location selection. Selecting a suitable location requires close attention to public needs, optimization of land use (Kordi and Yousefi, 2022), easy and convenient access, economic justification, and harmony with other urban components (Mohamad et al., 2015). Vacant lands in the city are among the first and foremost options available for building shopping centers.

Vacant lands are areas that have not yet been developed and have no buildings, which are considered critical and strategic assets in urban planning (Mohamad Selamat et al., 2023). Their unique importance can be emphasized in two ways. On the one hand, vacant lands are limited resources in terms of area in urban environments. Population growth and urban development make it necessary to take the most advantage of these resources (Song et al., 2020). On the other hand, vacant lands are considered potential places for transforming the urban landscape, boosting economic development, and creating public and social spaces (Mao et al., 2022). With the help of proper planning, these lands can be turned into facilities and urban structures such as shopping centers, entertainment centers, and green spaces, with major positive effects on the quality of life of citizens and the sustainable development of the city (Wesener, 2015; Kim et al., 2020). Therefore, it is crucial to analyze the suitability of these lands for various uses, including the construction of shopping centers.

The suitability of urban vacant lands for building a shopping center is determined by various factors such as access and traffic (McClintock et al., 2013), population and regional needs (Pearsall et al., 2014), economy and market (López et al., 2021), infrastructural and spatial observations (Kirnbauer and Baetz, 2014), environmental effects (Branas et al., 2018), urban development strategies (Kim, 2016), and sustainability in the face of natural hazards (Gaillard, 2007). Hence, these factors must be taken into account when investigating the suitability of vacant lands. In general, assessing the suitability of vacant lands for the construction of a shopping center is a multi-criteria and spatial issue. In previous studies, it was shown that spatial multi-criteria decision-making (SMCDM) along with geographic information system (GIS) are powerful tools for making different decisions in the urban environment by considering different criteria (Afsari et al., 2022, 2023; Shahpari Sani et al., 2022; Ali et al., 2023). By combining various spatial criteria, these systems provide the possibility to analyze, evaluate, and select suitable locations for urban projects (Dutta et al., 2023). So far, many GIS-SMCDM models have been used to select suitable locations for building shopping centers. For example, Erdin and Akbaş (2019) used the Fuzzy TOPSIS model to determine suitable locations for building shopping centers in Turkey. Ghorui et al. (2020) used the AHP-TOPSIS model to select an optimal location for a shopping mall in and around the city of Kolkata, West Bengal, India. Deb (2012) used the fuzzy AHP model to select suitable locations for the construction of a shopping center from the point of view of customers. Önüt et al. (2010) proposed a combined GIS-SMCDM method to determine the optimal areas for building a shopping center. They used Fuzzy AHP to allocate criteria weights and Fuzzy TOPSIS to determine the most suitable location. In summary, GIS-SMCDM-based systems evaluate criteria and select optimal locations using the analytical methods presented in Table 1.

Attitudes of decision-makers can be effective in determining optimal locations for building shopping centers. Decision-makers have different attitudes in terms of risk tolerance, including a wide range of very optimistic to very pessimistic. The models used in previous studies to select the optimal locations for the construction of the shopping center did not consider the attitude of the investors. The Ordered Weighted Averaging (OWA) model is an efficient method for SMCDM which accounts for the investor risk attitudes. The OWA model is more accurate in being flexible and adapting to individual preferences, which helps decision-makers select the best locations according to their views. This model can also cope with uncertainty in data and evaluations while accounting for their effects. In short, this model offers the potential to enhance decision-making quality and optimize location selection thanks to its flexibility, capacity to handle ambiguities, and adaptability to individual preferences.

Therefore, the main purpose of this study is to assess the potential of urban vacant lands based on a spatial multi-criteria decision-making (SMCDM) system for building a shopping center in 22 districts of Tehran. Contributions of this research include (1) the emphasis on vacant lands as manageable areas in the field of urban development, including the construction of a shopping center and (2) using the OWA model to produce potential maps of vacant lands, taking into account the attitudes of decision-makers and investors.

2 Materials and methods

2.1 Study area

Tehran is the largest city and capital of Iran and the capital of Tehran province with a population of 9,162,550 people and an area of 730 km^2. The city covers the altitudes 35°36′ to 35°44′ N and longitudes 51°17′ to 51°33′ E. It is located in the north of Iran to the south of the Alborz mountain range, 112 km south of the Caspian Sea. Tehran is the 38th most populated capital in the world and the 24th largest city in the world. The city has a dense network of highways and seven active subway lines that move more than 2.5 million passengers on average every day (Figure 1).

TABLE 1 Analytical methods used in GIS-SMCDM to evaluate criteria and select optimal locations.

Method	Description	Advantages	Disadvantages	References
AHP	Compares criteria and options using a matching matrix, and suitable places are selected through matching criteria and criterion weights.	Accuracy in combining criteria and options and making decisions.	Dependence on determining appropriate weights and computational complexity in some cases.	Sipahi and Timor (2010), Ivlev et al. (2014), Németh et al. (2019), Jorge-García and Estruch-Guitart (2022)
Fuzzy AHP	This method combines adaptive hierarchical analysis with fuzzy principles to deal with uncertainties in decision-making.	Flexibility in managing ambiguities and density of information to make decisions in situations with partial or ambiguous data.	More computational complexity than traditional AHP and often requiring efficient analyst interaction with fuzzy concepts.	Sipahi and Timor (2010), Wittstruck and Teuteberg (2012), Taylan et al. (2014)
Fuzzy TOPSIS	It uses fuzzy logic to evaluate ambiguous criteria and options. Options are then prioritized using criteria weights and option scores.	More accurate management of ambiguities and uncertainties in decision-making due to data fuzziness and information density.	Requires sufficient knowledge of fuzzy concepts and related mathematical combinations, and higher computational complexity than traditional TOPSIS.	Krohling and Campanharo (2011), Taylan et al. (2014), Baki (2020)
Concordance analysis	In this method, the criteria and options are compared using an agreement matrix, and the locations with the most agreement with the criteria are selected.	Assessing alignment and compatibility between different data in MCDA to choose better options and create less interference.	The need to determine a certain level to evaluate data alignment, and the possibility of dependence on the order determined for the criteria in decision making.	Kwiecien et al. (2011), Meek et al. (2014)
ANP	This method is an extension of AHP, which also considers the relationships between criteria and their interactive effects. It analyzes the cross-connections between criteria and sub-criteria.	Evaluating cross effects between criteria in multi-criteria decision-making.	Computational complexity and the need for knowledge of network analysis.	Hernández et al. (2010), Chou (2018), Shorabeh et al. (2021)
VIKOR	This method pays attention to the positive and negative criteria and the places that have the best balance between the criteria are selected.	Paying attention to minimum congestion and maximum proximity to the ideal center in choosing the best option.	The need to determine the weighting parameters may become problematic in complex problems.	Jahan (2012), Zimonjić et al. (2018), Zheng and Wang (2020)
ELECTRE	This method uses the matching matrix and compares the positive and negative criteria and the places that match the positive criteria and those that do not match the negative criteria are selected.	Managing ambiguity and preference in decision-making with flexibility in determining criteria parameters.	Complexity in determining parameter values and the need for analyst expertise to perform this method correctly.	Figueira et al. (2010) and Zheng and Wang (2020)
PROMETHEE	This approach is employed to assess and rank discrete options and select the most favorable option by considering multiple criteria with different measurement scales.	Managing complex and adaptive configurations in MCDM.	The need for analyst expertise to correctly perform this method and the complexity in determining criteria parameters.	Venkata Rao and Patel (2010), Brans and De Smet (2016), Oubahman and Duleba (2021)
MAUT (Multi-Attribute Utility Theory)	In this method, using multi-criteria valuation theory, the preferences and priorities of different criteria are determined using sub-evaluation functions, and the criteria are optimized.	Converting different criteria into quantitative values and ordering options based on their value in MCDM.	The need for expertise in determining the transfer function and criteria preferences and the possibility of exact compliance with the views of decision-makers.	Kailiponi (2010), San Cristóbal Mateo and Mateo (2012), Allah Bukhsh et al. (2019)

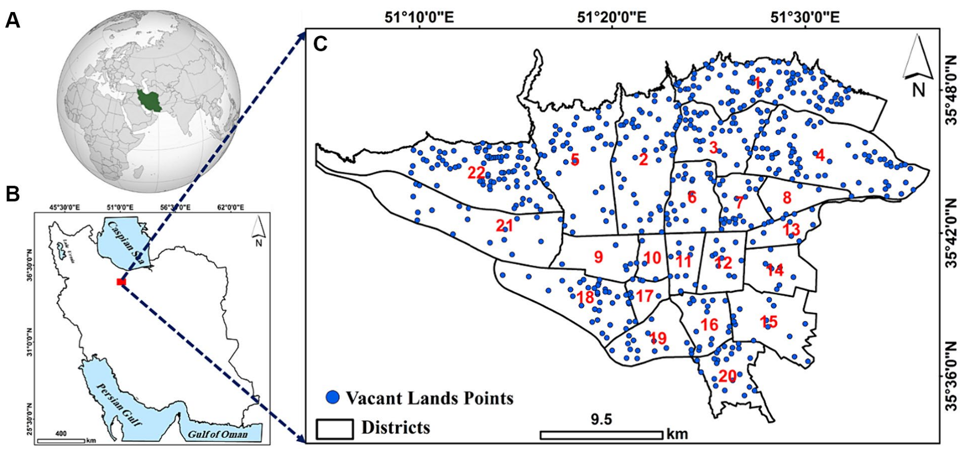


FIGURE 1
(A) Iran's position in the world; **(B)** location of Tehran in Iran; and **(C)** location of vacant lands points in Tehran districts.

TABLE 2 Characteristics of urban areas of Tehran.

Municipal districts	Area (ha)	Population	Household	Number of vacant lands
1	4661.2	543,311	195,420	90
2	4700.5	743,408	265,231	51
3	2921.7	352,155	130,101	38
4	6155.5	962,073	332,789	68
5	5316.1	905,056	324,419	41
6	2136.7	271,107	95,572	23
7	1533.5	313,115	121,939	24
8	1315.6	474,056	169,694	4
9	1974.7	190,793	63,996	6
10	818.5	337,883	128,493	3
11	1203.1	318,082	115,736	10
12	1600.7	239,635	81,144	11
13	1286.3	230,645	116,152	9
14	1455.3	512,232	172,637	8
15	2774.1	675,837	223,382	12
16	1651.5	254,409	85,541	15
17	825.2	312,619	103,240	7
18	3786.9	442,798	144,051	35
19	2034.2	272,472	84,255	16
20	2,358	387,281	127,288	23
21	5152.5	201,952	69,898	18
22	5900.3	221,631	73,421	79
Whole study area	61562.1	9,162,550	3,224,399	591

Source: https://www.tehran.ir/.

According to the statistics of 2016, Tehran's share in the total gross domestic product of Iran is 27%, and it plays an important role in Iran's economy by allocating half of the country's industrial sector to itself. In addition, this city accounts for about 20% of the country's population, 24% of value-added in the industry sector, and 38% of the service sector in the entire country. Therefore, determining suitable areas for the construction of a shopping center is of great importance in this city. Population growth, heavy traffic and population density are important factors in decision-making the location of shopping centers in Tehran. Also, different districts of Tehran city have different characteristics in terms of residential density, commercial density and access to transportation. All these factors have made vacant lands become valuable assets and strategic locations with inherent potentials for urban development. Tehran is divided into 22 districts, 134 regions, and 376 neighborhoods. The total number of vacant lands considered for this study is 591. These vacant lands are considered as proposed places for building commercial centers on the urban land use map prepared by Tehran Municipality. Some characteristics of Tehran's urban areas are shown in Table 2.

2.2 Research data

The research data included datasets that have a spatial nature. These consisted of two groups: remote sensing data (i.e., slope raster data) and data collected from related organizations [i.e., vector data on highway networks, public transportation stations, existing shopping centers, land price, rental rate, entertainment and tourist centers, per-capita income, service centers, fault lines, stream networks, traffic and air pollution plan, population density, parks, central business district (CBD) and crowded centers]. The geographic locations of vacant lands suitable (e.g., legally) for building a shopping center were sourced from Tehran Municipality. The data specifications are presented in Table 3. Finally, after collecting the primary data layers, spatial analysis was conducted in QGIS to produce and analyze the information layers and prepare the criteria map considering their capabilities at each stage. IDRISI was used to prepare shopping mall potential maps under different scenarios.

2.3 Methodology

Figure 2 shows the main steps of the research method (five main steps). (1) At this stage, by using expert opinions, library sources, and

TABLE 3 Research data.

Data	Format	Resolution/Scale	Source
Highway networks	Vector/polyline	1:2000	https://www.mrud.ir/en/
Public transport stations	Vector/point	1:2000	https://en.ncc.gov.ir/
Existing shopping centers	Vector/point	1:2000	https://www.tehran.ir/
Land price	Vector/polygon	District scale	https://www.amar.org.ir/english
Entertainment and tourist centers	Vector/point	1:2000	https://en.ncc.gov.ir/
Per-capita income	Vector/polygon	District scale	https://www.amar.org.ir/english
Slope	Raster	30 m	Extracted from the digital elevation model of Aster Satellite (https://earthexplorer.usgs.gov/)
Service centers	Vector/point	1:2000	https://en.ncc.gov.ir/
Fault lines	Vector/polyline	1:2000	https://gsi.ir/en
Traffic and air pollution plan	Vector/polygon	District scale	https://www.tehran.ir/
Population density	Vector/polygon	Sub-district scale	https://www.tehran.ir/
Parks	Vector/point	1:2000	https://en.ncc.gov.ir/
CBD	Vector/point	1:2000	https://en.ncc.gov.ir/
Rental rate	Vector/polygon	District scale	https://www.amar.org.ir/english
Stream networks	Vector/polyline	1:2000	https://en.frw.ir/
Crowded centers	Vector/point	1:2000	https://en.ncc.gov.ir/
Vacant lands	Vector/point	1:2000	https://www.tehran.ir/

previous studies, the effective criteria for building shopping centers were identified and the necessary data was collected to create a spatial database. (2) The second stage involved pre-processing operations (to unify the coordinate system of the layers) and spatial analysis in GIS (to prepare criteria maps). (3) At this stage, the data were standardized to allow for direct comparison of different units. Then, the weight and importance of the criteria were calculated using the BWM method. (4) At this stage, benchmark maps and their weights were introduced as input to the OWA model, and a potential map was created for the construction of shopping centers in the study area. (5) At this stage, the number of shopping centers in 22 districts of Tehran was determined. (6) Finally, to evaluate the results obtained from the OWA model in measuring the potential of building shopping centers and determining the best scenario, the opinions of the stakeholders were used from the obtained map.

2.3.1 Criteria used

Various criteria are involved in measuring the potential of urban vacant lands for the construction of a shopping center, meaning that it is a multi-criteria decision-making process. Therefore, 16 spatial criteria were identified based on the conditions of the study area, library sources, expert opinions, and previous studies. Table 4 provides a description of each criterion and how to extract it.

2.3.2 Standardization of criteria

Data standardization, also known as data de-scaling, is a method to change a diverse range of variable values into a uniform scale (Luo et al., 2023). In other words, a data explorer may encounter situations where the features in the data include values that are in different ranges or domains. Features with large values may have a much greater effect on the cost function than those with smaller values. This problem will be solved by standardizing the features so that their values are on a similar scale. After standardization, the values of all criteria fall into a 0–1 range. The values 1 and 0 in the criteria have different meanings. For example, in the criteria of distance from highway networks and distance from parks, 1 indicates areas with very low potential, whereas 0 indicates areas with very high potential for building shopping centers. In other words, by reducing the distance, the number of potential areas for building shopping centers increases. On the other hand, in the criteria of distance from the stream network and distance from fault lines, 1 indicates areas with very high potential and 0 indicates areas with very low potential. In other words, as the distance increases, the potential areas for building shopping centers increase. Therefore, Equation (1) is used for the first type criteria, and Equation (2) is used for the second type criteria.

$$z_{ij} = \frac{Z_j^{max} - Z_{ij}}{Z_j^{max} - Z_j^{min}} \tag{1}$$

$$z_{ij} = \frac{Z_{ij} - Z_j^{min}}{Z_j^{max} - Z_j^{min}} \tag{2}$$

Where, z_{ij} is the standardized score for the ith decision alternative and the jth criterion, Z_j^{min} and Z_j^{max} are, respectively, the minimum and maximum values of score importance, and Z_{ij} is the score of the criterion (Wang et al., 2011).

2.3.3 Best-worst method

The best-worst method, as a multi-criteria decision-making method, was used here to calculate the weight and importance of criteria. In MCDM methods, criteria are evaluated to choose the

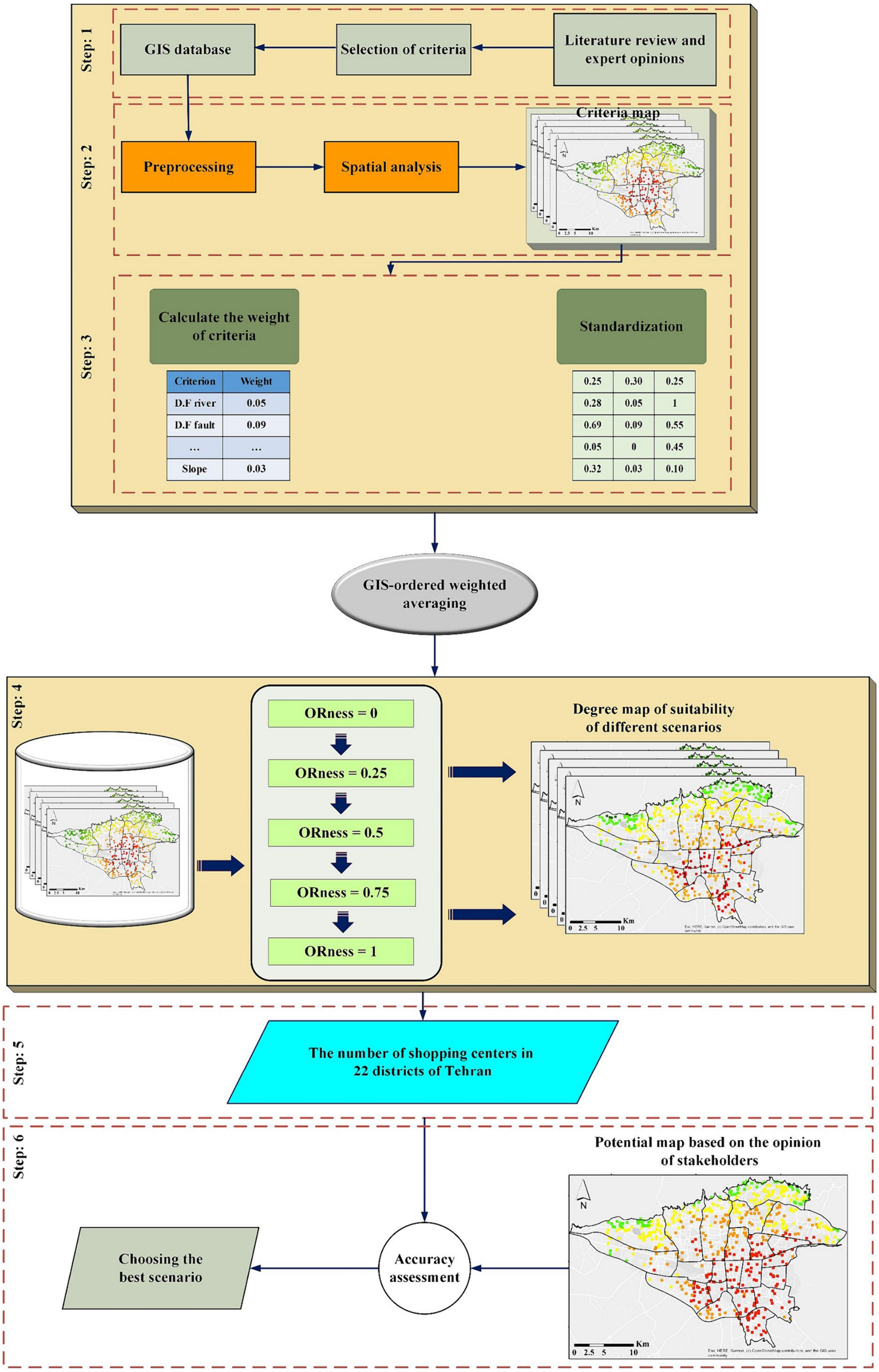


FIGURE 2
Flowchart of the main research steps.

TABLE 4 Description of the research criteria.

Criteria	Description
D.F highway networks	Highways make travel faster, easier, and safer while reducing fuel consumption (Ghorui et al., 2020). For this reason, the shorter the distance from the highways, the higher the suitability. The Euclidean Distance tool was used to prepare this map.
D.F public transport stations	Proximity to high-speed public transportation stations such as metro and bus rapid transit (BRT) is of great importance due to saving time in urban traffic and low prices compared to private cars (Koçak, 2010). As the distance from public transportation stations increases, suitability decreases. The Euclidean Distance tool was used to prepare this map.
D.F existing shopping centers	One of the most important and effective criteria for choosing suitable places to create new shopping centers is the distance from the existing shopping centers. A greater distance from the existing shopping centers means more customers and better public service (Saleh and Abdullah, 2023). The Euclidean Distance tool was used to prepare this map.
Land price and rental rate	With the increase in the price of land and rent, the demand for building shopping centers decreases. Due to the high costs, these areas cannot be accessed by the general public, undermining both the customer base and its economic viability (Zolfani et al., 2013). Therefore, areas with low land prices and rent were considered as priority areas. The Polygon to Raster tool was used to prepare this map.
D.F entertainment and tourist centers	Proximity to entertainment and tourist centers can have a positive effect on the income of shopping centers. Larger populations will visit, however, the fluctuating customer demand pattern can cause certain challenges (Önüt et al., 2010). The Euclidean Distance tool was used to prepare the distance map from the entertainment and tourist centers.
Per capita income	An increase in *per capita* income will in turn increase the demand for purchases and vice versa. Hence, areas with high *per capita* income have a higher potential for building shopping centers. The Polygon to Raster tool was used to prepare this map.
Slope	The rise in slope results in higher construction and equipment relocation expenses (Shorabeh et al., 2019). Therefore, the lower the slope, the greater the potential. The Slope tool was used to prepare the slope map.
D.F service centers	Service centers in this study include fire stations, hospitals, police stations, and public parking lots. Proximity to these centers guarantees the safety of citizens, integrity of infrastructure, and public well-being (Erdin and Akbaş, 2019). The Euclidean Distance tool was used to prepare this map.
D.F fault lines and stream networks	Proximity to fault lines and stream networks can cause serious damage to urban infrastructure, while also threatening human life and property (Shorabeh et al., 2020). The Euclidean Distance tool was used to prepare this map.
Traffic and air pollution plan	There are certain restrictions in place in the Tehran metropolis to control air pollution and traffic. Private vehicles entering restricted zones are fined. Therefore, people may avoid visiting them, meaning that these areas have a lower potential. The Polygon to Raster tool was used to prepare this map.
Population density	A high population density leads to an increase in the number of customers and the chances of commercial success (Cheng et al., 2005). Therefore, areas with high population density were considered as priority. The Density tool was used to prepare this map.
D.F parks	Parks are important hubs of population concentration as they offer recreational and entertainment amenities, with positive effects on the income of shopping centers (Kazemi and Amiri, 2017). Therefore, the shorter the distance from the parks, the greater the suitability potential. The Euclidean Distance tool was used to prepare this map.
D.F CBD	The central business district has a high rate of travel attraction as it has a diverse range of land uses and houses vital urban functions and activities (Ghorui et al., 2020). Therefore, the proximity to these districts increases the degree of suitability. The Euclidean distance tool was used to prepare this map.
D.F crowded centers	Squares and intersections are major population hubs for citizens, commuters, and people visiting from nearby cities to do their business and administrative affairs (Saleh and Abdullah, 2023). Proximity to these hubs has a positive effect on the income of shopping centers. The Euclidean Distance tool was used to prepare this map.

best option (Taherdoost and Madanchian, 2023). Based on the best-worst method presented by Rezaei (2015), the best (most important, most desirable) and worst (least important, most undesirable) criteria are determined by the decision maker. Then pairwise comparisons are made between each of these criteria with other criteria. The advantages of this method compared to previous similar methods are: (1) it requires less comparative data and (2) this method leads to a more stable comparison; i.e., more reliable answers (Rezaei, 2016).

In this method, after determining the criteria and the best and worst options, the preference of the best criteria over other criteria and the preference of the other criteria over the worst criteria is determined using a Saaty (2004) scale. The result will be the two vectors $A_B = (a_{B1}, a_{B2}, \ldots, a_{Bn})^T$ and $A_W = (a_{1W}, a_{2W}, \ldots, a_{nW})^T$. Where, A_B indicates the preference of the best criterion over the jth criterion and A_W indicates the preference of the j criterion over the worst criterion. Then, the optimal weight of the criteria is calculated based on Equation (3):

$$\min \xi$$

$$s.t.$$

$$\left| \frac{w_B}{w_j} - a_{Bj} \right| < \xi, \text{for all } j,$$

$$\left| \frac{w_j}{w_w} - a_{jw} \right| < \xi, \text{for all } j,$$

$$\sum_j w_j = 1$$

$$w_j \geq 0, \textit{for all } j \quad (3)$$

By solving this equation, the optimal weights $\left(w_1^*, w_2^*, \ldots, w_n^*\right)$ and ξ which represent the incompatibility ratio are obtained (Gigović et al., 2019). The closer the inconsistency value is to zero, the higher the compatibility of the criteria pairwise comparisons (Karakuş, 2023).

2.3.4 Potential mapping

The OWA method was used to prepare a potential map of urban vacant lands for the construction of a shopping center due to its greater flexibility and power in the decision-making space. This method, presented by Yager (1988), combines a weighted sum with the prioritization of evaluation criteria, thus considering both criteria weights and their prioritization (Malczewski, 2006). The prioritization of weights enables the direct control of the criteria. This method can calculate investor risk tolerance and use it in choosing the final option (Firozjaei et al., 2019), leading to a continuous ranking of scenarios between the risk-averse (intersect) operator and the risk-taking (union) operator (Malczewski et al., 2003). It can be said that the OWA method is a relatively new combination that is similar to the WLC method but includes two sets of weights (Malczewski, 2004). The advantage of the OWA method is that the researcher can create a wide range of predictions and scenarios by sorting and changing the parameters of each criterion (Boloorani et al., 2021).

The OWA method includes two groups of criteria weights and order weights. Criterion weights are given by considering the decision maker's preference for a certain criterion or feature in the study area (Malcezewski, 2006). This is because the relative importance of that criterion is determined compared to other existing criteria, but order weights are assigned based on the location of cells of layers and maps (Xu, 2005). Therefore, all the cells of a map have a common criterion weight, but their order weight is different. The OWA method can produce results very similar to those of AND, OR, and WLC operators. Because these methods are a subset of OWA. The final states of this method are shown by AND and OR operators and are related to MIN and MAX operators, respectively (Malczewski et al., 2003). In the first case, the highest value is given to the largest value of the criteria. This optimistic approach has maximum risk tolerance and no trade-off (Mahmood et al., 2023). On the other hand, the highest value is given to the lowest criterion (i.e., pessimistic approach with minimal risk) (Zhang et al., 2021), which has no trade-off. Meanwhile, there are a large number of criteria sets with different degrees of trade-off. More details of the OWA method are provided in Shorabeh et al. (2019).

In the OWA method, a factor called ORness determines the degree of risk in decision making. Its value range is between 0 and 1. In this study, potential maps were prepared in 5 different scenarios including ORness = 0 (very pessimistic), ORness = 0.25 (pessimistic), ORness = 0.5 (intermediate), ORness = 0.75 (optimistic) and ORness = 1 (very optimistic). The values of the potential maps obtained from these scenarios vary between 0 and 1. Value 0 represents the lowest and value 1 represents the highest potential for building shopping centers. Finally, the maps obtained from different scenarios were classified into five classes, very low (0–0.2), low (0.2–0.4), medium (0.4–0.6), high (0.6–0.8), and very high (0.8–1), based on the degree of potential.

2.3.5 Accuracy assessment

The evaluation of the results obtained from the OWA model was used to assess the potential of building shopping centers and determine the best scenario from the opinions of stakeholders including 50 investors. Based on this, the weight of the effective criteria on choosing the right location of shopping centers was determined by the stakeholders. Then, based on the weighted linear combination model, the weight and standardized values of the criteria were combined with each other. In the next step, a classification map of the potential of building shopping centers including very low (0–0.2), low (0.2–0.4), medium (0.4–0.6), high (0.6–0.8), and very high (0.8–1) classes were prepared. Finally, the spatial compatibility of the areas classified as very high potential in different scenarios of the OWA model and the stakeholder map was investigated. For this purpose, overall spatial accuracy and prediction rate metrics were calculated for each scenario.

3 Results

The calculated weights for the criteria based on BWM are shown in Figure 3. Distance from highway networks (0.108), distance from transportation stations (0.105), population density (0.09), rental rate (0.085), and distance from existing shopping centers (0.08) had higher weights than other criteria. Moreover, distance from faults and distance from stream networks had the least weight in determining land suitability. The average weights of access, economic-social, and natural-environmental groups were 0.071, 0.065, and 0.036, respectively. The importance of access group criteria was higher than other criteria. The consistency rate in the BWM model was less than 0.01, which indicates the high consistency of expert opinions in determining criteria weights.

The map of the criteria used in determining the potential of vacant lands is shown in Figure 4. The spatial distribution of effective criteria values is heterogeneous across the studied area. In terms of traffic plan criteria and pollution, central vacant lands (e.g., CBD) had the lowest suitability, and vacant lands located in the outer parts of the city had the highest suitability. The vacant lands in the northern parts of Tehran had a higher slope, which means less suitability for building a shopping center. The central, southeastern, and southern regions of Tehran had a higher population density than other regions and were more suitable. The land and rent prices in the northern areas were higher than in the southern areas; meaning that the southern areas are more suitable. On the contrary, in terms of *per capita* income, vacant lands in the northern regions had a higher suitability since *per capita* income is higher in these regions. Vacant lands in the central areas had a higher priority than the peripheral areas due to their proximity to CBD. In terms of the distance from faults, due to earthquake risks, vacant lands located in the northern and southern regions had a lower suitability than vacant lands in the central regions. Due to the concentration of stream networks in the northern half of Tehran city, vacant lands in these areas are at risk of flooding and have a lower suitability. Vacant lands in marginal areas are less suitable due to their greater distance from public transportation stations, crowded areas, and recreational and park areas. In addition, the vacant lands located in the southwest and eastern regions are more suitable than other vacant lands due to their greater distance from the existing shopping centers. In terms of the distance from highways, vacant lands located in the northwestern regions had a lower suitability.

The potential map of vacant lands in Tehran city for the construction of a shopping center under different scenarios is shown in Figure 5. Vacant lands with high and very high potential were located in the south and southeast of Tehran. On the other hand, vacant lands located in the north and northeast of Tehran had low and very low potentials.

Examples of vacant lands designated as very high potential areas under a very pessimistic scenario are shown in Figure 6. These lands are located in areas with high population density, close to highways, public transportation stations, and crowded areas of the city. These lands are also suitable in terms of economic criteria such as land price, rental rate, and slope. They are outside of the traffic and pollution plan (restricted areas) and at a close distance to CBD, parks, and recreational and service areas. For investors with a very low risk tolerance, these vacant lands are the best options for building a shopping center.

The number of vacant lands within each potential degree class under different scenarios is presented in Figure 7. The number of vacant lands with very high potential based on very pessimistic, pessimistic, intermediate, optimistic, and very optimistic scenarios was 29, 95, 105, 122, and 224, respectively. This number was 161, 82, 14, 4, and 2 for vacant lands with very low potential. Under the very pessimistic scenario, only 5% of the vacant lands had a very high potential, while in the very optimistic scenario, this value reached 38%. The results show that with the increase in the degree of optimism, the number of vacant lands with high and very high potential increased and the number of vacant lands with low and very low potential decreased.

The percentage of vacant lands with a very high potential compared to the total number of vacant lands in different regions is shown in Table 5. Under a very pessimistic situation, districts 4, 5, 7, 10, 11, 14, 15, and 16 had vacant lands with a very high degree of potential. District 10 had three vacant lands, all of which have a very high potential under all five scenarios. Under the most optimistic scenario, all urban districts had high-potential vacant lands. Under this scenario, 100% of vacant lands located in districts 8, 10, 11, 12, 13, 14, 16, 17, 19, and 20 had a very high potential, while this value for districts 1 and 22 was about 1%. The lowest percentage of vacant lands with very high potential was in District 5 at about 12%. With the increase in the degree of optimism in the decision-making process, the percentage of high-potential vacant lands increased in all urban areas.

The potential map of building shopping centers based on the opinions of stakeholders is shown in Figure 8. The number of 4, 73, 205, 144, and 165 vacant lands were placed in very low, low, moderate, high and very high potential classes, respectively. These results show that according to the opinion of the stakeholders, about 28% of vacant lands in Tehran has a very high potential for building shopping

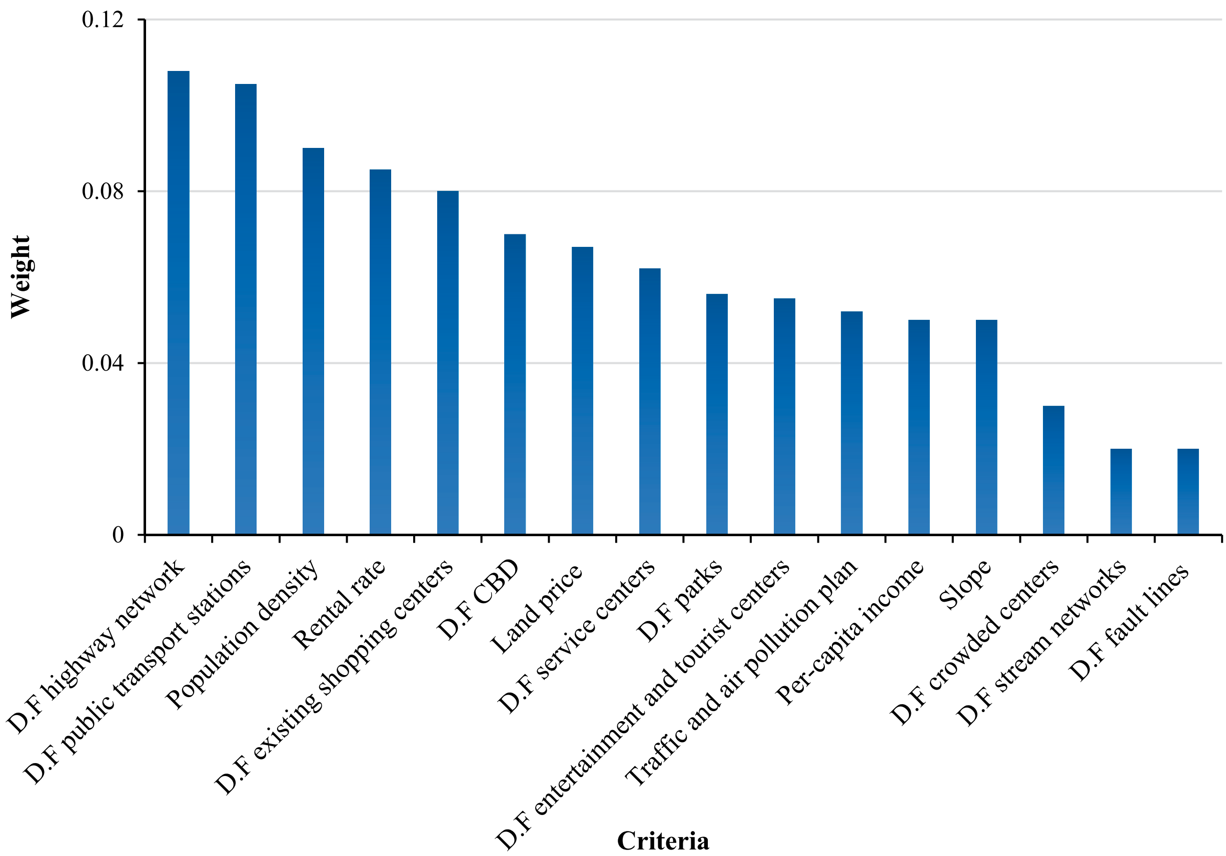


FIGURE 3
Weights calculated based on BWM for effective criteria in determining suitable locations.

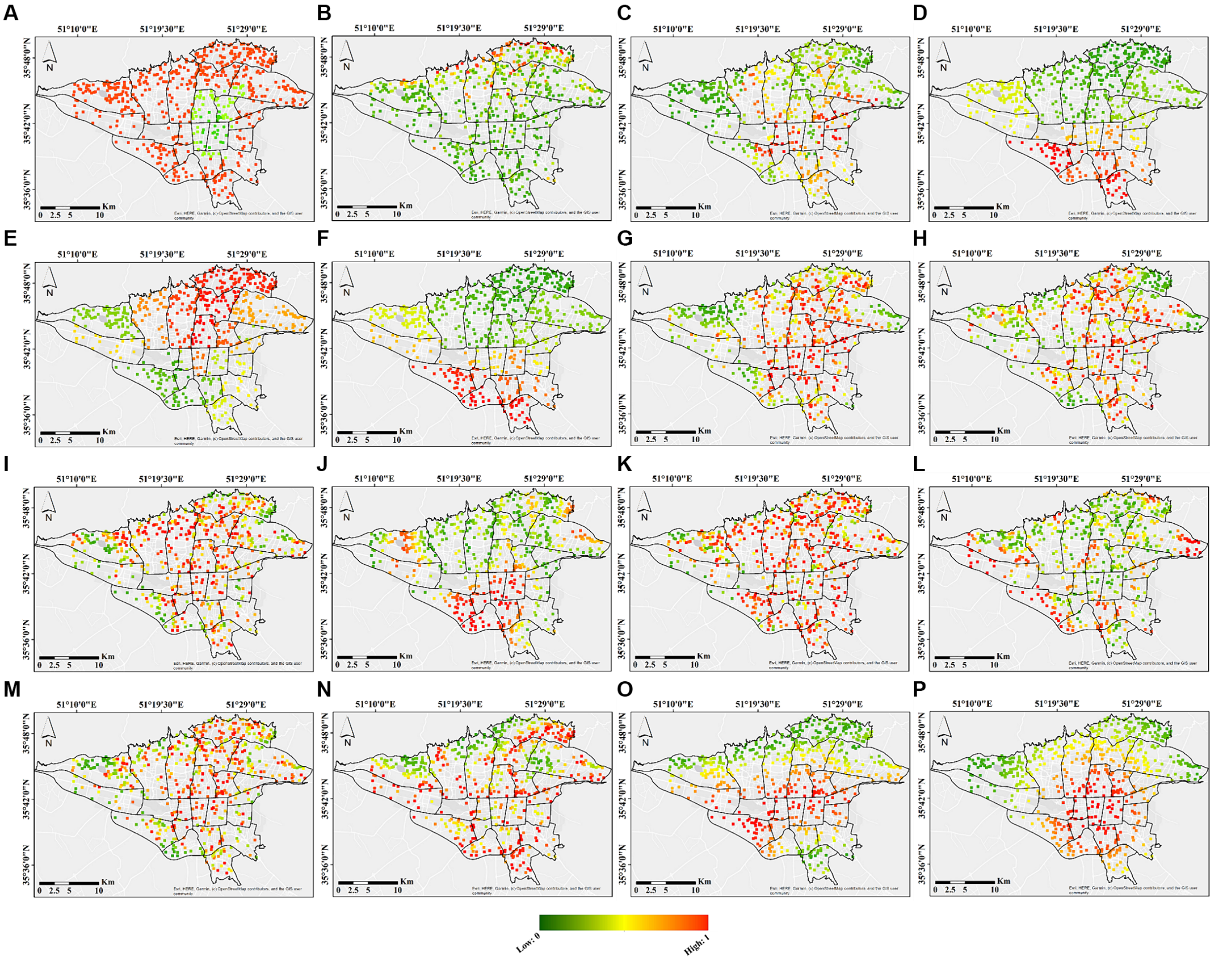


FIGURE 4
Map of the criteria used in determining the potential of urban vacant land for the construction of a shopping center; **(A)** traffic and air pollution plan, **(B)** slope, **(C)** population density, **(D)** rental rate, **(E)** per-capita income, **(F)** land price, **(G)** D.F public transport stations, **(H)** D.F entertainment and tourist centers, **(I)** D.F crowded centers, **(J)** D.F stream networks, **(K)** D.F parks, **(L)** D.F existing shopping centers, **(M)** D.F service centers, **(N)** D.F highway networks, **(O)** D.F fault lines, **(P)** D.F CBD.

centers. Most of the vacant lands with very high potential are located in the central and southern areas of Tehran.

The results of evaluating the accuracy of different OWA scenarios using the obtained map based on the opinion of the stakeholders are shown in Figure 9. The overall spatial accuracy for very pessimistic, pessimistic, intermediate, optimistic and very optimistic scenarios is 0.15, 0.52, 0.58, 0.68, and 0.72, respectively. Based on this criterion, the scenario very well has the best performance in evaluating the potential of vacant lands for building shopping centers. However, this scenario suggests a large number of vacant lands as optimal locations. In order to normalize the number of proposed vacant lands, the prediction rate was calculated. To calculate the prediction rate of overall spatial accuracy in each scenario, it was divided by the ratio of the number of vacant lands with very high potential to the total vacant lands of the study area. The prediction rates of very pessimistic, pessimistic, intermediate, optimistic and very optimistic scenarios are 0.83, 0.89, 0.90, 0.92 and 0.53, respectively. Based on this metric, the optimistic scenario has the best performance in evaluating the potential of vacant lands for building shopping centers.

4 Discussion

In urban studies, it is worthwhile to assess the potential of urban vacant lands as unique opportunities for urban development. These lands can become strategic points with direct effects on traffic, citizen well-being, employment, and regional economy (Ghorui et al., 2020). Exploitation of these lands can improve some urban problems such as population density, traffic, and lack of space (Devi and Yadav, 2013). Shopping centers as important economic and social hubs can help create employment, attract tourists, and increase public welfare (Wang et al., 2014). According to the existing restrictions, vacant lands in cities can be great options for building shopping centers. Determining the potential of vacant lands requires a detailed and multi-criteria evaluation. By using various criteria, MCDM systems, and special algorithms, it is possible to obtain more accurate results and optimal plans for urban vacant lands. This study investigated various criteria such as traffic, population density, geographical distances, income, land price, and access to public facilities. This diversity in criteria allows for obtaining a more accurate picture of land potential.

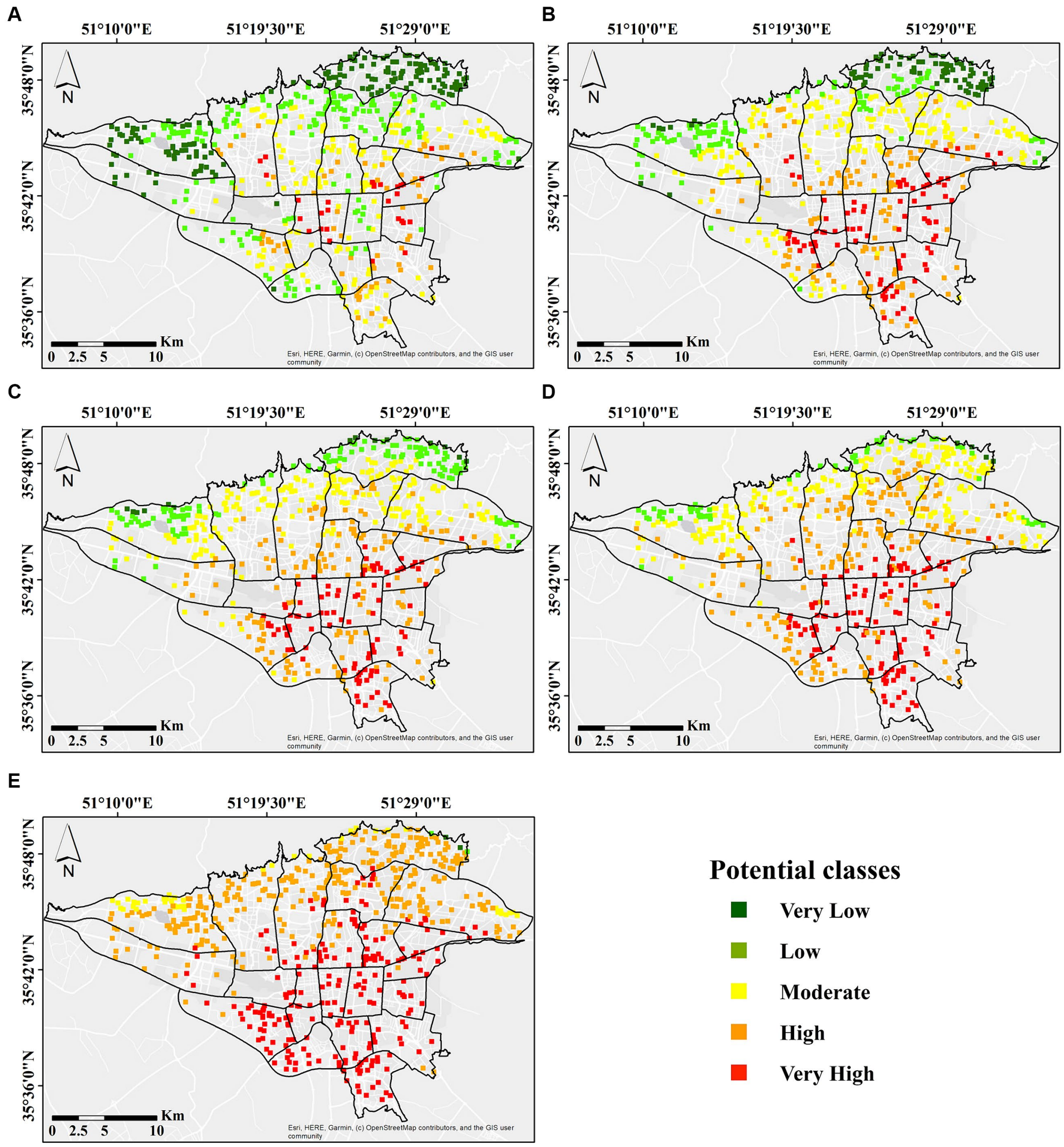


FIGURE 5
Potential map of Urban vacant lands for the construction of a shopping center; **(A)** very pessimistic, **(B)** pessimistic, **(C)** intermediate, **(D)** optimistic, and **(E)** very optimistic.

Considering that assessing the potential of vacant lands for the construction of a shopping center is affected by various spatial criteria, the use of spatial MCDM systems plays an important role in analyzing the potential of these vacant lands. These systems combine and properly weigh criteria, making it possible to compare different locations. BWM is a popular MCDM method for weighting, with the advantage that reference comparisons select the best criterion over other criteria as well as other criteria over the worst criterion (Rezaei, 2015). This method is much simpler and more accurate and eliminates additional (secondary) comparisons (Kazemi-Beydokhti et al., 2019). However, BWM also has disadvantages, including sensitivity to changes in the weights given by experts (Wu et al., 2021). Small changes in the weights may lead to large changes in the order of priority of the criteria and thus the final decision (Yazdi et al., 2022). In addition, the process of gathering expert opinions may be time-consuming and complicated (Moradi et al., 2023). As a result, the use of BWM requires precision and specialized knowledge in the process to achieve reliable and dynamic results. Meanwhile, the OWA model, which operates based on risk in decision-making, is often used to prepare potential maps of vacant lands under different (very pessimistic, pessimistic, intermediate, optimistic, and very optimistic) risk tolerance scenarios. This model plays an important role in optimizing location decisions due to its ability to manage different risks and balance them. Previous studies have used OWA for land use suitability assessment (Luan et al., 2021; Feizizadeh

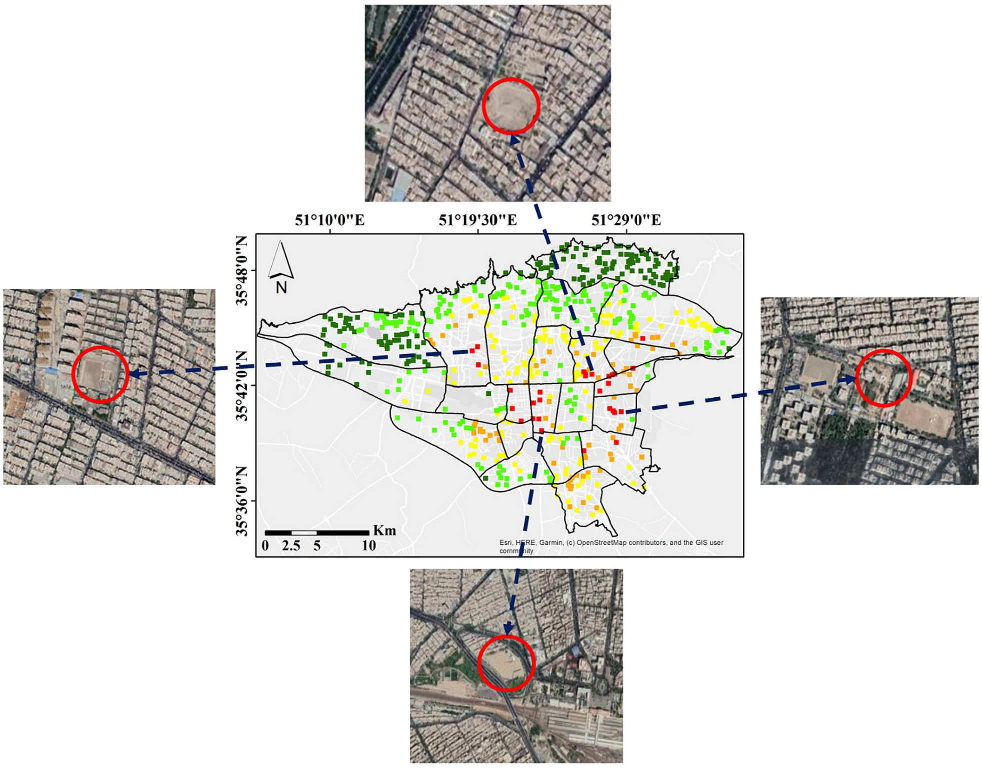
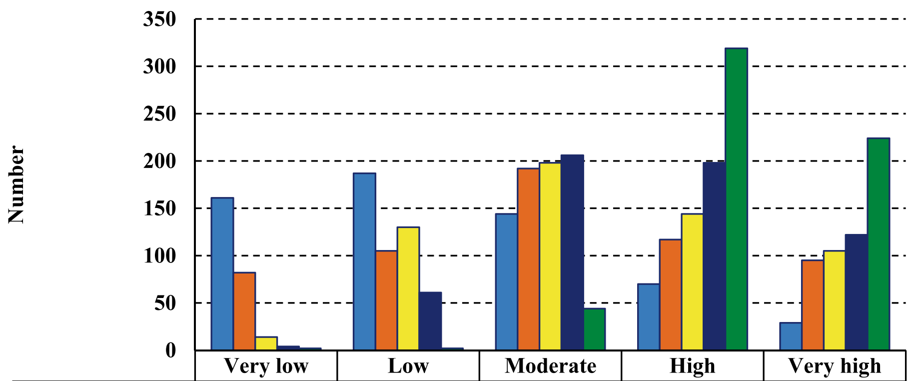


FIGURE 6
Samples of vacant lands designated as areas with very high potential for building a shopping center under a very pessimistic scenario.



	Very low	Low	Moderate	High	Very high
Very pessimistic	161	187	144	70	29
Pessimistic	82	105	192	117	95
Intermediate	14	130	198	144	105
Optimistic	4	61	206	198	122
Very optimistic	2	2	44	319	224

FIGURE 7
The number of vacant lands located in each class of potential for building a shopping center under different scenarios.

et al., 2023), locating suitable areas for renewable energy power plants (Shorabeh et al., 2022; Cheng et al., 2023), risk modeling and vulnerability to natural hazards (Ghaffari Gilandeh et al., 2020; Yariyan et al., 2020), evaluating thermal comfort in the urban environment (Mijani et al., 2019), predicting the physical growth of cities (Karimi Firozjaei et al., 2020), etc. The results of these studies confirm the accuracy and flexibility of the OWA model in multi-criteria decisions.

Although spatial MCDM systems are powerful tools for land potential analysis, they also have limitations. These limitations include partial or inappropriate data, temporal changes in measures, and sensitivity to changes in measure weights. Furthermore, considering

TABLE 5 The percentage of high-potential vacant lands compared to the total number of vacant lands for the construction of shopping centers in municipal areas under different scenarios.

Municipal districts	Very pessimistic	Pessimistic	Intermediate	Optimistic	Very optimistic
1	0	0	0	0	1.1
2	0	0	1.9	3.9	37.2
3	0	0	0	0	34.2
4	1.4	8.8	1.4	1.5	17.6
5	7.3	9.7	2.4	4.9	12.2
6	0	0	0	21.7	82.6
7	33.3	45.8	58.3	62.5	83.3
8	0	50	50	50	100
9	0	0	66.6	66.6	83.3
10	100	100	100	100	100
11	60	100	100	100	100
12	0	36.3	54.5	90.9	100
13	44.4	77.7	55.5	55.5	100
14	50	87.5	37.5	37.5	100
15	25	66.6	66.6	66.6	91.6
16	0	33.3	46.6	86.6	100
17	0	100	100	100	100
18	0	40	40	48.5	97.1
19	0	0	12.5	31.2	100
20	0	69.5	73.9	91.3	100
21	0	0	0	0	16.6
22	0	0	0	0	1.2

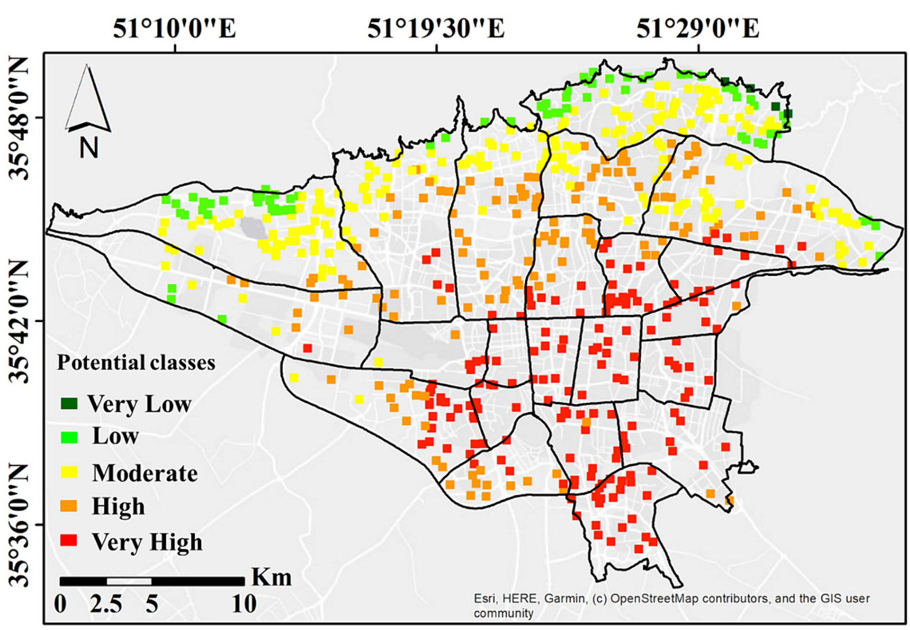
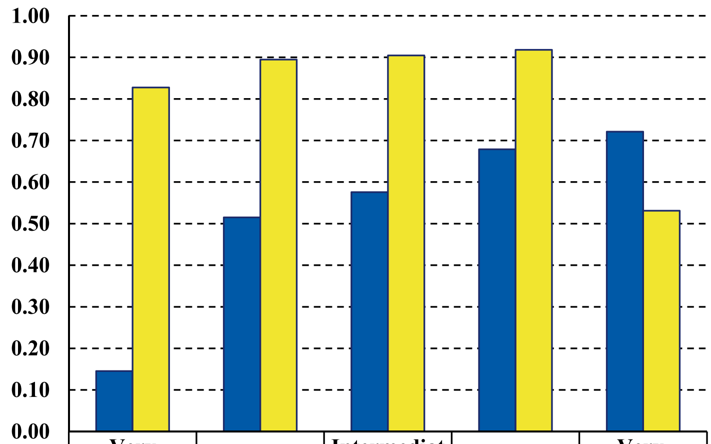


FIGURE 8
Map of the potential of building shopping centers based on the opinion of stakeholders.



	Very pessimistic	Pessimistic	Intermediate	Optimistic	Very optimistic
Overall spatial accuracy	0.15	0.52	0.58	0.68	0.72
Prediction rate	0.83	0.89	0.90	0.92	0.53

FIGURE 9
The results of evaluating the accuracy of different OWA scenarios using the obtained map based on the opinion of the stakeholders.

all criteria may cause a lot of complexity in the model and affect its performance. In short, the analysis of the potential of vacant lands for the construction of shopping centers using various criteria and spatial MCDM systems is an important tool for urban planning and improving urban spaces. However, it is necessary to carefully evaluate the limitations of these methods to make optimal decisions.

In this study, the preparation of maps of effective criteria in evaluating the potential of building shopping centers was faced with several challenges. Among the challenges in collecting data from different sources are the lack of a location portal for searching, evaluation and access, the lack or problems of metadata, and the lack of necessary coordination between different organizations for sharing data and location information. Also, different standards have been used in the production of the required data in the preparation of criteria maps. These standards include coordinate system, format, spatial accuracy, pixel size, method and date of data production. The different standards of the datasets used in the preparation of the criteria map cause and increase the uncertainty in the potential measurement maps for the construction of shopping centers. However, to unify some standards such as coordinate system, format, and pixel size, tools have been developed in spatial software, which are used in this study in the pre-processing stage. On the other hand, to update the results of measuring the potential of building shopping centers in the coming years, up-to-date data is needed, and accessing all these data can be challenging.

5 Conclusion

Identifying suitable areas for specific urban development purposes is one of the basic issues in regional plans and land development faced by urban planners. Assessing the potential of major commercial centers is a key step in regional development. The proper distribution of these centers in terms of political and social dimensions can drive economic growth and reduce regional inequality. Therefore, this study assessed the potential of urban vacant lands based on SMCDM for the construction of a shopping center in the 22 districts of Tehran. The results showed that accessibility criteria (such as distance from highways) have more weight and importance than other criteria for the construction of shopping centers. The southern and southeastern regions of the study area had a higher potential. The generated potential maps showed that the number of vacant lands with high and very high potential changes with the change of attitude (from very optimistic to very pessimistic). The number of vacant lands with very high potential was 224 under a very optimistic attitude and 29 under a very pessimistic attitude. A very optimistic attitude can be used when there is neither a high sensitivity nor a constraint on the allocation of resources, whereas a very pessimistic decision-making attitude can be used when there are both very high sensitivity and certain economic limitations. Results showed that of the 22 districts of Tehran, in 10 districts all vacant lands were suitable for building shopping centers under a very optimistic scenario, and only 1 district under a very pessimistic scenario.

Data availability statement

The data analyzed in this study is subject to the following licenses/restrictions: they should be collected from related organizations at personal cost and have a high volume. Requests to access these datasets should be directed to FN, nickravesh.f@ut.ac.ir.

Author contributions

JK: Conceptualization, Data curation, Methodology, Software, Writing – original draft. SQ: Supervision, Writing – review &

editing. SR: Conceptualization, Data curation, Formal analysis, Methodology, Writing – original draft. BM: Conceptualization, Investigation, Methodology, Writing – original draft. PD: Formal analysis, Resources, Writing – original draft. SY: Software, Validation, Writing – original draft. KJ: Formal analysis, Software, Writing – original draft. RA: Investigation, Validation, Writing – original draft. FN: Data curation, Resources, Validation, Writing – original draft.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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