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Article

Potential measurement and spatial priorities determination for gas station construction using WLC and GIS

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ABSTRACT

Improper location of gas stations leads to waste of resources, time, and user dissatisfaction. On the other hand, the optimal location of these facilities will have a significant impact not only on the quality of traffic in the network but also on their economic success. The aim of this research is the spatial-physical organization of inner-city structures with an emphasis on the location of gas stations using the weighted linear integrated model method on the GIS platform using the descriptive-analytical method. First, the location of the existing stations and the areas that need gas stations were determined using the weighted linear integrated model (WLC) and ArcGIS. A scoring-based method was used to convert the maps into a standard scale ranging from 0 to 1 and 0 to 255. The Analytical Hierarchy Process (AHP) method and the Expert Choice app were used to determine the criteria weights. Then, the GIS and WLC capability to provide a suitable model for locating stations was tested. The result states that for the construction of gas stations, the Bahmanyar region will be the priority. North Khani Abad region is the second priority, and South Khani Abad and Esfandiari regions are the following priorities. Finally, with the local investigation of the prioritized areas by WLC, it was found that these areas are suitable for constructing gas stations. This method can be used for finding a suitable location for gas station construction in all other cases.

1. Introduction

With the increase in population in big cities, the public services demand has increased [1]. Also, with more usage of cars, the need to create multiple fuel stations has increased. Iran is one of the owners of fuel reserves in the world, and for a long time, gasoline and diesel have been used as two common car fuels, like most countries in the world. Population growth and improper development of cities have created many problems for cities, and principled spatial organization of urban services can be very effective to a large extent in regulating the performance of cities [2]. The issue of land and how to use it is considered the leading platform of urban planning [3]. Equitable access to land and its optimal use and organization is also considered an essential component of sustainable development. Today, the concept of urban spaces and places has changed qualitatively both from a natural and physical point of view and from an economic-social point of view. It has made the dimensions of land use planning and place organization very diverse and rich. The physical system of the city and the urban space is considered a public resource and life and wealth of the public and public good. Its usage can be carefully managed to provide public benefits in the present and future [4]. Various methods and solutions have been presented in different parts of the world to determine the suitable location for gas stations. For example, in Switzerland, a study has been conducted by determining the desirability of the stations in the form of maximizing the objective function whose parameters include the factors influencing the desirability of the station, and the location has been finalized, which has been done by using one of the mathematical optimization models and applying it to the mentioned objective function [5]. In Malaysia, the amount of incoming traffic to the station is recognized as a parameter that indicates the desirability of the station location. In this research, with the regression modeling method, a function that includes various station characteristics has been defined to estimate the amount of incoming traffic to the station. Using the resulting function, traffic forecasting in candidate points determines the suitable places for the station's construction [6]. In Iran, according to the distribution of traffic volume in the transportation network, gas station localization has been done by using an optimization method [7]. The evaluation that is carried out on the plans at different levels and stages in selecting the best solutions from among the different options makes sure that the material and resources of the plans are not wasted. Wherever a mistake happens, the agency will find out and fix the defect. The existence of a robust evaluation system that controls projects at different stages can be of great help in achieving the project's goal [8]. The basis of the evaluation is to measure the relative merit of different solutions. In short, improving the living quality of the community, comprehensiveness, increasing participation, uncertainty, comprehensiveness, and the use of defined and targeted criteria are among the features considered during the evaluation [9]. On the other hand, one of the most critical issues in urban planning is the placement of urban services. This means that various urban activities require suitable spaces, and it is not possible to establish them in every area of the city. Therefore, the placement of any urban element in a specific physical-spatial position of the city is subject to certain principles, rules, and mechanisms, which, if followed, will lead to the success and functional efficiency of that element in the same place [10]. The essential optimal criteria in determining suitable locations for urban activities and services can be listed as follows [11]:

- Compatibility: placing compatible usages next to each other and separating incompatible uses from each other.
- Comfort: distance and time are important factors in measuring the level of users' comfort because, as a result of providing them, ease of access to city services, which is one of the main goals of urban planning, becomes possible.
- Efficiency: means that the chosen place is optimal from an economic point of view [12].
- Desirability: means preserving and maintaining natural factors and creating open and pleasant spaces according to the location of roads, buildings, and urban spaces.
- Health: It means compliance with health standards.
- Safety standards: The goal is to protect the city against possible dangers [13].
- Research main question: According to the above studies, in this research, the main question is can we reduce the problem of traffic and crowding by optimizing the location of new fuel stations in the studied area (19th district of Tehran)?
- Research assumption: several parameters can be examined to locate fuel supply stations, such as population density, access to the road network, available gas stations, etc., and examining each of the above factors requires a lot of statistics and information.

Many studies have been done on locating urban services using different techniques and methods. WLC and GIS are important methods in determining the optimal location of urban uses, which have been used in various levels of this system. Some of the research conducted with various models and their results are mentioned in Table 1. The main task of this research is to help urban planners and decision-makers determine the optimal location of gas stations so that all urban residents can easily access them.

Table 1. Summary of studies and research background

Research title	Authors	Publication year	Results
Spatial modeling of areas suitable for public libraries construction by integration of GIS and multi-attribute decision making: Case study Tehran, Iran	Shorabeh et al. [14]	2020	They standardized the research indicators with spatial analysis and overlapped them at the last stage. The results indicate that positions No. 2, 108, 115, 145, and 153 are located in optimal locations, positions 15, 22, and 110 are located in partly suitable locations, and position No. 24 is located in an inappropriate position.
A review on criteria and decision-making techniques in solving landfill site selection problems	Mat et al. [15]	2017	The results of this research indicated that 7% of Tehran municipality's district 5 has excellent potential, 26% has medium potential, and 67% is unsuitable for the construction of a gas fuel station. Also, the results of their location survey were done with the existing stations, and they observed 33% matching in areas with high potential and 17% in areas with medium potential.
Assessment of sustainable urban development based on a hybrid decision-making approach: Group fuzzy BWM, AHP, and TOPSIS–GIS	Foroozesh et al. [16]	2022	It was concluded that a very limited part of the northern Karaj watershed has the appropriate capacity for urban development.
Site selection for multi-story car parks with emphasis on urban sustainable development management	Shafiei Nikabadi and Hashemi [17]	2021	They considered and suggested three points suitable for the construction of multi-story parking lots.
Site selection for small gas stations using GIS	Mohammadi and Ali [18]	2011	The results of this research have focused on the importance of fuel stations and their important role in reducing traffic nodes, safety and the environment.

2. Case study

The city of Tehran currently has 22 municipal districts, and the studied area is located in district 19, located in the south of Tehran (Figure 1). District 19 of Tehran is from 51 degrees 6 minutes to 51 degrees 38 minutes east longitude and from 35 degrees and 34 minutes to 35 degrees and 51 minutes north latitude. It is one of the peripheral areas of the city of Tehran that has undergone its formation process during the last 30-40 years. District 19 is adjacent to district 17 from the north, district 16 from the east, and district 18 from the west. This district has five regions. Zamzam Street and Ayatollah Saeidi Highway form the common border between District 19 and neighboring areas in the north and west. Bahmanyar Street and the northern part of Tondgouyan Highway are the eastern borders between District 19 and District 16, and it is limited to Azadegan Highway from the south [19]. The 19th district of Tehran is located in the entrance area of southwest Tehran, has a special place, and contains some of the structural elements of the city. The area of this district is currently over 2032 hectares, which is about 3.16% of the area of Tehran (64396 hectares).

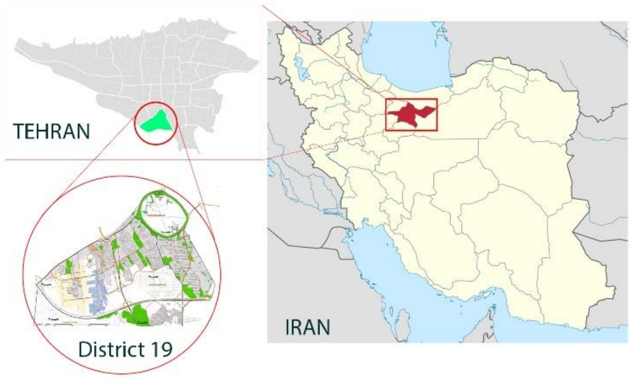

Figure 1. Case study location

3. Methodology

The method of this study is descriptive-analytical, and its type is practical. The statistics and information required are collected through documents referring to the 19th district municipality of Tehran, libraries, and field studies at the regional level, then to analyze the information and determine the current status of the stations. The WLC model was used in the GIS environment, which includes five steps in the following order to determine the appropriate location for gas stations. In addition to combining all the parameters or layers, the WLC method also considers the importance of each parameter based on the weight given to that parameter. As a result, the map resulting from WLC locating has a high ability to provide suitable options.

3.1 Criteria

To determine suitable areas for constructing gas stations, criteria are needed to locate based on them. For this purpose, after reviewing the sources and using the opinions of the expert group, the criteria for the location of the gas station were considered, which are listed in Table 2. It represents the general condition of the proposed site. They were taken into consideration, while the necessity of using operations such as overlay, search, spatial analysis, ground reference, and rasterization provided a turning point for the effective use of ArcGIS software in this research. Table 3 shows the required geospatial data.

3.2 Preparation of benchmark maps

To analyze the compatibility, the layer of roads, the layer of residential areas, etc., and the information layer related to gas stations were extracted from the digitized maps of land use in the ArcGIS environment. Then, after determining the square coordinates of the studied area and the number of rows and columns in the cellular network, the extracted benchmark maps were imported into the ArcGIS environment and saved as raster maps to be used in the next step using the Distance function [25].

3.3 Standardization (fuzzification) of benchmark maps

The benchmark maps used in this research were on different scales, and it was impossible to perform arithmetic operations on them. Accordingly, the method based on the score range was used to eliminate the effect of different scales and convert them into a standard scale between zero to one and zero to 255. In this procedure, the following equations are used [26].

$$\frac{x_{ij}-x_j^{min}}{x_j^{max}-x_j^{min}} = X'_{ij} \quad (1)$$

$$\frac{x_j^{max}-x_{ij}}{x_j^{max}-x_j^{min}} = X'_{ij} \quad (2)$$

X'_{ij} : Standardized score concerning the option j and the attribute i
X_{ij}: Raw score
X_j^{max} : Maximum score for attribute i
X_j^{min} : Minimum score for attribute i
X_j^{max} - X_j^{min} indicates the range of values related to the attribute i.
The value of standardized scores can be between 0 to 1 and 0 to 255 [27]. In this research, using the features that exist in the fuzzy function of ArcGIS to standardize the maps that were prepared in the form of standard maps is used appropriately in formats such as uniformly increasing patterns and uniformly decreasing patterns. Figure 2 shows an example of standardized layers resulting from fuzzy functions.

3.4 Data weighting method

In this research, to determine the weight of the criteria, the two-by-two comparison method, which is used under the Analytical Hierarchy Process (AHP) method, was used. In this method, the conceptual complexity involved in decision-making is significantly reduced because, at any given time, only two components are considered (Table 4, Figure 3). At this stage, Expert Choice software and the method AHP was used to produce the importance coefficients of the criteria. Table 5 shows the prioritizing location criteria by AHP method.

3.5 Multi-criteria evaluation through the weighted linear combination method (WLC)

The multi-criteria evaluation aims to select the best options based on their ranking by evaluating several main criteria. There are several methods to analyze the evaluation of several criteria, the most important of which include the Weighted Linear combination method, Value/Utility Function, AHP, Ideal Point, and the Concordance method. The weighted linear combination method is the most common technique in multi-criteria evaluation analysis that has been widely used in the GIS environment.

Table 2. Effective parameters in the location of gas station stations

Compatible parameters		
 **Fire stations:** the potential and risk of danger in different areas of the city, according to the number and frequency of incidents, leads to identifying vulnerable points in fire incidents and places with high potential [20]. Therefore, the access of fire stations to fuel stations leads to reduce these damages.	 **Bus terminals and stations:** City buses are one of the most important parts of city transportation. The small distance between the terminals and stations to reduce the access time to fuel stations leads to the improvement of services to citizens.	 **Public parking lots**: the proximity of parking lots to gas stations leads to ease of refueling. Otherwise, traveling a long distance for this purpose will lead to increased crowding and congestion in neighborhoods, fuel consumption, neighborhood pollution, and noise pollution.

Incompatible parameters			
 **Schools:** Exposure to chemical compounds in gasoline can lead to adverse health effects such as asthma, headache, and cancer [21]. Due to the high vulnerability of children and teenagers to substances affecting health, the distance of schools from these fuel stations reduces these damages.	 **Hospitals**: Sick people desperately need a healthy environment. Avoiding the proximity of hospitals to gas stations is necessary, considering that gasoline is placed in the first tier of cancer risk by international health associations [22].	 **Residential areas:** Establishing a calm and safe environment for urban residents requires staying away from gas stations. Due to noise pollution and health damage from fuel stations, the distance of stations from these areas is one of the urban planning goals [23].	 **Parks:** Urban parks have various functions, including air pollutant absorption and purification, microclimate stabilization, and temperature adjustment [24]. it is necessary to avoid the vicinity of parks and gas stations because of the chemical composition of gasoline and the accumulation of cars at gas stations.

Table 3. Required geospatial data

Data type	Data sample
Visual (Raster)	Area elevation model (Dem)
Vector	Roads and streets layer
	Available gas stations layer
	Natural hazards layer (faults)
	Public parking lots layer
	Bus terminals and stations layer
	Fire stations layer
	Schools and educational centers layer
	Hospitals and medical centers layer
	Parks layer
	Residential areas layer
Descriptive	Area population information layer

This technique is called the Simple Additive Weighting and Scoring method [28]. This method is based on the concept of weighted average. The decision-maker directly assigns weights to the criteria based on the relative importance of each considered criterion. Then, by multiplying the relative weight by the value of that attribute, a final value is obtained for each alternative. After the final value of each alternative is determined, the alternative with the highest value will be the most suitable alternative for the intended purpose, which can be the optimal land suitability for a specific application (for example, a gas station). The weighted linear combination method based on GIS includes the following steps:

1. Specifying a set of evaluation criteria (map layers) and sets of possible options.
2. Standardization of each layer of the benchmark map.
3. Determining the criterion weight so that relative importance weight is directly assigned to each criterion map.
4. Creating standardized map layers (by multiplying the standardized map layers by their corresponding weights).

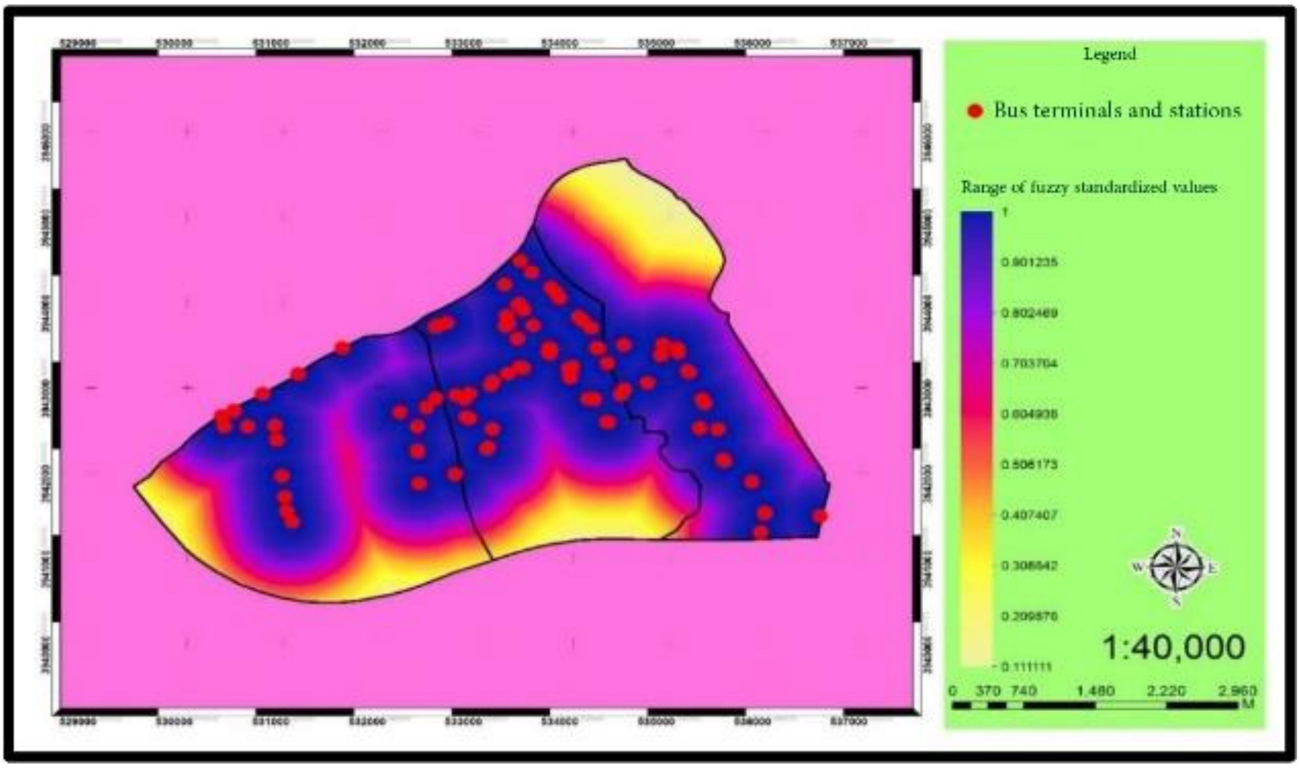

Figure 2. Standardized fuzzy map of distance from city bus terminals and stations

Table 4. Criteria used in gas station location

Variable	X1	X2	X3	X4	X5	X6
description	Distance from existing gas stations	Distance from main roads and streets	Distance from the fault	Distance from public parking lots	Distance from the fire station	Distance from bus terminals and stations
Variable weight from AHP method	0.071	0.1	0.148	0.029	0.153	0.025
Variable	X7	X8	X9	X10	X11	X12
description	Area population	Distance from schools and educational centers	Distance from hospitals and medical centers	Distance from parks	Distance from residential areas	The slope of the area
Variable weight from AHP method	0.052	0.035	0.149	0.104	0.072	0.062

5. By applying the collective overlap operation on the layers of the weighted standardized map, the total score is calculated for each option, and the options are ranked according to the total functional score. Furthermore, the option with the highest score (rank) is the best. Formally, in the decision rule to evaluate each option or Ai, equation 3 is used:

$$A_i = \sum_{j=1}^{n} W_j X_{ij} \quad (3)$$

X_{ij}: The score concerning option i and the attribute j

W_j: The weight for criterion j

This research carried out the WLC operation in the ArcGIS environment. In addition, the output of the WLC model was standardized with a simple linear stretch using the STRETCH function in the range of 0-255 to compare the scores of the options with the desired situation. The weighted linear combination (WLC) method can also be implemented using the geographic information system and the overlapping capabilities of this system. Overlay techniques in the geographic information system allow us to combine and combine them to produce a composite map layer (output map). This method is practical in the geographic information system's raster and vector formats [29].

Table 5. Prioritizing location criteria by AHP method

Priority	Variable	Weight
1	fire station	0.153
2	hospitals and medical centers	0.149
3	Natural hazards (faults)	0.148
4	parks	0.104
5	main roads and streets	0.100
6	residential areas	0.072
7	existing gas stations	0.071
8	The slope of the area	0.062
9	Area Population	0.052
10	schools and educational centers	0.035
11	public parking lots	0.029
12	bus terminals and stations	0.025

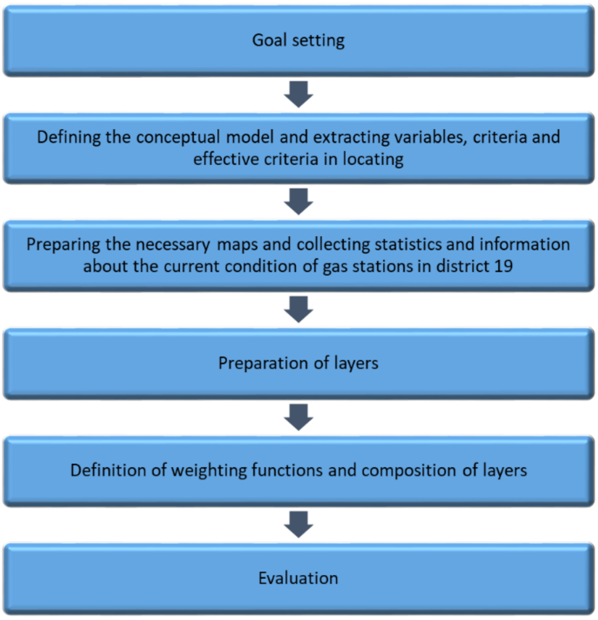

Figure 3. Gas station location flow diagram

4. Discussion

4.1 Distribution of gas stations in the 19th district of Tehran

According to Figure 4, gas station service coverage is unsuitable in district 19. There is no proper distribution between the usages mentioned earlier at the region's level. Hence, the northern and western areas of the city have good access to gas stations. However, the eastern and southeast areas and peripheral areas do not have gas stations, including North and South Khani Abad, Bahmanyar, Esfandiari, South Shariati, and Ismail Abad. In Tehran's 19th district, based on the current situation, there are five gas stations named Mehran station in Abdul Abad, station 186 in Sports Street in Abdul Abad, station 187 in Nemat Abad police station on Shahid Kazemi highway, station 204 in Azadegan Kholazir and station 207 in Azadegan wet market. According to Figure (4), their spatial distribution is such that this service use has gathered in the north and southwest of the city, so other areas do not have easy access to the existing stations. As a result, the center, southeast, and northeast regions suffer from the lack of this service, which indicates the incorrect location of this service in the region.

4.2 Location assessment of gas stations

In general, the optimal location of gas station centers is one of the crucial issues affecting the city's economy from various dimensions. In other words, inappropriate distribution of the mentioned uses, in addition to spending high transportation costs to access them, wastes citizens' time and creates roadblocks and traffic nodes, and the resulting costs are not possible to calculate most of the time. Therefore, positioning is a locating analysis that significantly impacts reducing costs, increasing accessibility, and launching various activities. For this reason, it is considered one of the most important and practical implementation projects. As mentioned, after preparing the standardized maps to each of the mentioned criteria in measuring the level of desirability of the location for the establishment of a gas station and applying the relevant weights, the resulting maps are entered into the WLC model, and by applying different steps on the maps, the final output was obtained. As shown in Figure 5, the range of changes in the resulting value is categorized from 0.26 to 0.54. Lands with low values have the lowest land suitability for allocating gas stations, respectively; with the increase in the range of values, the suitability of lands for the construction of said stations also increases, so the highest suitability is related to lands with a value of 0.49 and above. Therefore, in equal conditions for allocating land to a gas station, priority is given to land with a higher value. In any case, the values shown on the map can help decide on the suitable land to allocate to a gas station at the regional level. Of course, it should be noted that the prioritization shown has been obtained according to the criteria used and their weight. If other uses in the current state occupy the zones with high scores, if it is not possible to change the use or it is not cost-effective, one should go to the following priorities. This model significantly reduces the limitations and complications caused by a large amount of information and the inconsistencies caused by the diversity of the nature of the criteria and also reduces the duration of calculations and analysis. At the same time, it has relatively good accuracy. In analyzing the location of gas station stations, in addition to the weighted linear combination (WLC) method, fuzzy methods such as AHP and integrated methods such as fuzzy AHP can be used. The limitations of the research increased. However, one of the advantages of the weighted linear combination model is the simplicity and speed of operation of this model despite the high accuracy in positioning. Also, weighting gives the decision-maker the power to consider the more important factors that he considers to be the location problem. It affects it with the same importance in the problem, and due to this superiority, positioning by the WLC method has a better resolution between the spectrums in it.

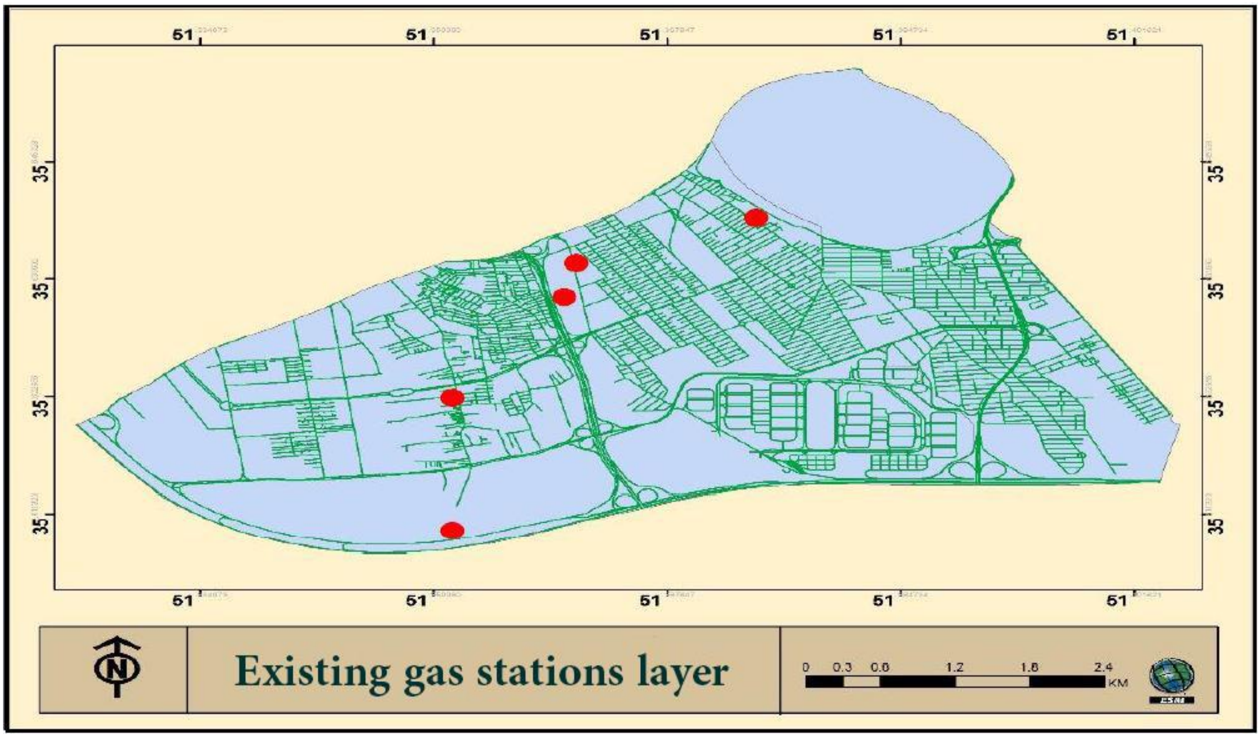

Figure 4. The spatial distribution of gas stations

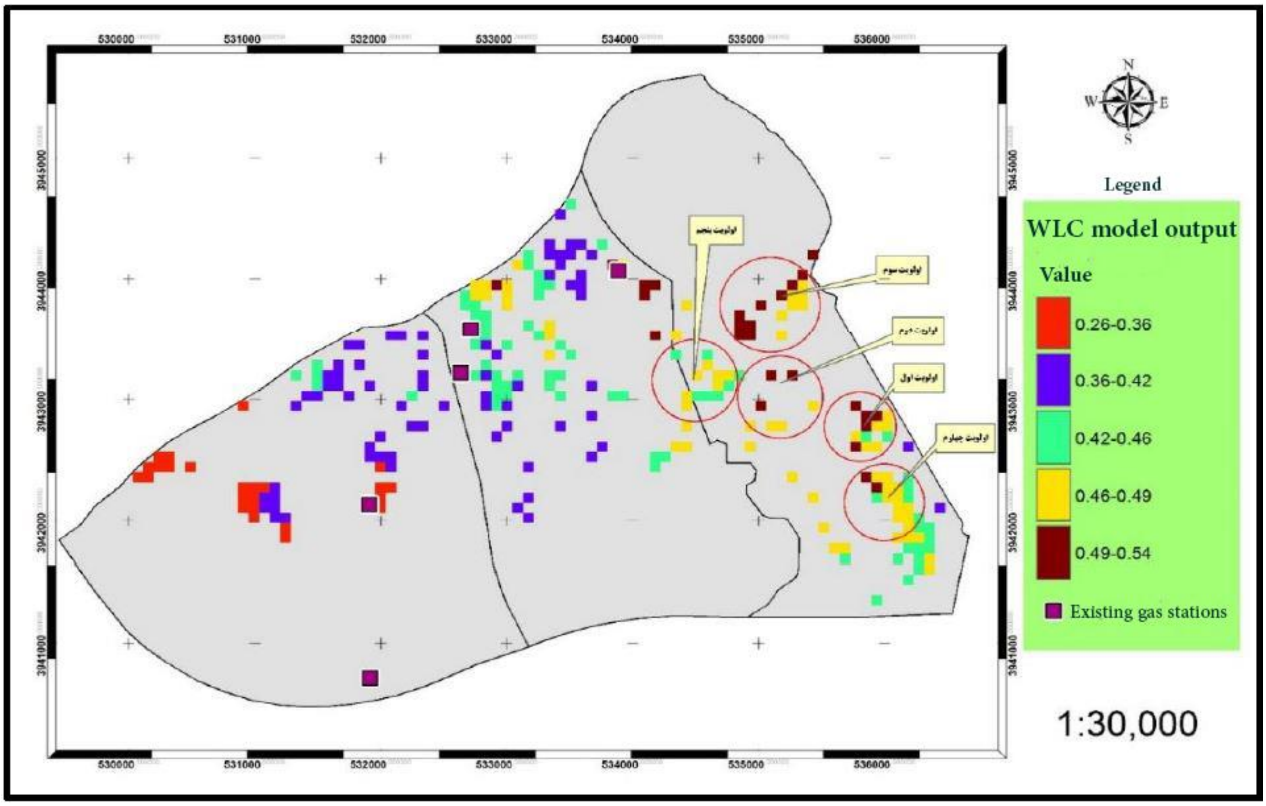

Figure 5. The leveled map of spatial suitability in relation to the establishment of a gas station based on the output of the WLC model

5. Conclusion

Gas stations are one of the critical urban service uses due to their performance and impact. In recent years, due to the rapid growth of urbanization and the reciprocal lack of comprehensive planning and management in the urban system of Iran, like other urban services, these spaces have also faced many problems, which are caused mainly by the small number, uneven and disproportionate distribution, lack of optimal location and lack of provision of suitable spaces for these uses in cities. According to the land use map and the field studies carried out on the distribution of the existing gas stations in the 19th district of Tehran, it was found that a large part of the area, despite the population density, proximity to first-class roads, etc., was outside the operating radius of the existing stations, which is the reason for the lack of gas stations to cover the entire region and the need to locate and establish new stations. The research results show that gas stations have a disorderly state in terms of expansion. Their accumulation in the center and southwest of the city has caused the central, southeast, and northeast areas to suffer from the lack of this use, which indicates the incorrect location of this use at the level of district 19. Therefore, the first hypothesis, "in the 19th district of Tehran, the spatial distribution of gas stations is unbalanced and does not match with common patterns and scientific models," is confirmed. On the other hand, the traditional methods of combining maps and evaluating several criteria often lack the necessary precision and accuracy due to multiple variables, the large area, etc. Statistical and mathematical functions in spatial analysis are either impossible or very difficult in traditional methods. However, as the results of these surveys show, it was found that by using the WLC model and the geographic information system capabilities and combining these two, it is possible to analyze and process a large amount of data and analyze difficult and complex issues. The final results of the research, which by case-by-case analysis of the priority pixels introduced in the output of the model, show that these pixels have high standardized scores at levels tending to 0.55 in most of the criteria used in land suitability evaluation; Therefore, the integration of this model with the geographic information system can be used by decision-makers as a decision support system (DSS) in the process of optimal location of gas station stations. So, the second hypothesis is also confirmed, "The weighted linear integrated model is a suitable model for the location of gas station stations in the 19th district of Tehran". This method can be used to find a suitable location for gas station construction all over the world.

Ethical issue

The authors are aware of and comply with best practices in publication ethics, specifically with regard to authorship (avoidance of guest authorship), dual submission, manipulation of figures, competing interests, and compliance with policies on research ethics. The authors adhere to publication requirements that the submitted work is original and has not been published elsewhere.

Data availability statement

Datasets analyzed during the current study are available and can be given following a reasonable request from the corresponding author.

Conflict of interest

The authors declare no potential conflict of interest.

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