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Subway Station Site Selection Using GIS-Based Multi-Criteria Decision-Making: A Case Study in a Developing Country

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Keywords

Multiple-Criteria Decision-Making (MCDM), Subway Stations, Analytic Hierarchy Process (AHP), Geospatial Information Systems (GIS), Optimum Locations.

Abstract

Public transportation plays an undeniable role in reducing congestion and air pollution in urban areas. This becomes especially critical for developing countries that are beginning to build these systems from the ground up. A variety of factors related to the population, their socioeconomic characteristics, and the broader environment should be considered to achieve project goals. Within this context, the Traffic and Transportation Agency of Rasht, Iran, intends to construct five subway stations along a proposed subway line for a planned future mass transit system in this city. This study aims to use geospatial analysis to determine the optimal subway station locations among a series of potential candidates which were recommended by the Traffic and Transportation Agency of Rasht. As such, different criteria based on the 2011 Rasht comprehensive transportation planning study and literature along with a GIS-based multi-criteria decision approach combined with an implementation of the Analytic Hierarchy Process (AHP) is used to select the best subway station locations. This approach can provide useful insights for the traffic and transportation agencies that are dealing with the site selection and urban planning problems specifically in the developing countries.

1. Introduction

Public transportation plays a significant role in reducing traffic congestion and air pollution in urban areas. These potential new benefits are quite compelling for developing countries considering building these systems from the ground up, as compared with many developed countries that already have existing comprehensive public transportation systems in place [1-3]. As such, when making new investments, a variety of factors related to population density, socioeconomic characteristics, and the environment in general should be taken into account in order to achieve project goals [4]. These and other factors have a direct bearing on these decisions given the increasing number of intra-city trips due to population growth, increasing urban development, and the heterogeneous dispersion of trip attractions such as offices, business centers, recreation centers and educational centers in cities [5]. This necessitates having a convenient and efficient public transportation system to meet people’s needs, while reducing congestion, fuel consumption and air pollution to more acceptable levels, through de-emphasizing the use of personal vehicles.

A subway system, especially, can be a viable travel alternative in larger cities; however, locating subway stations optimally is a challenging problem, which requires extensive analysis and accurate planning based on a host of data sources. If implemented successfully, these systems can also provide a variety of benefits in terms of speed, capacity, safety, reliability, separation from the surface traffic, and a reduction in overall environmental costs [6]. These benefits have been observed in many metropolitan areas around the world in comparison to other public transportation systems [7]. However, there are also many challenges associated with the implementation of these systems, especially during the planning phase, where agencies have to decide on the route configuration and station allocations [8]. For example, in order to alleviate traffic congestion-related problems, station locations must be homogeneous and they should be allocated strategically in order to serve the needs of the public most efficiently [9]. Furthermore, these systems are complex and there are many alternatives and mitigating factors to consider. For many cities, not giving enough attention to location-based concerns in the planning process has translated into congestion in some stations whereas other stations lack demand. The resultant travel patterns in these

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places suggest that inappropriate locations of stations will cause passenger delays in high demand areas [10].

When selecting a facility type, it is usually critical to determine the optimum location that would best satisfy the selection criteria and meet a number of objectives and constraints [11]. Such an optimization involves a variety of criteria, which are often contradicting, as the choice may be between selecting from a number of candidate sites, each having various advantages and disadvantages [12, 13]. For example, Alisan et al. [14] developed enhanced r-interdiction median (RIM) models to identify the most significant shelter(s) in a case study in Southeast Florida with two highly populated counties, Broward and Miami-Dade.

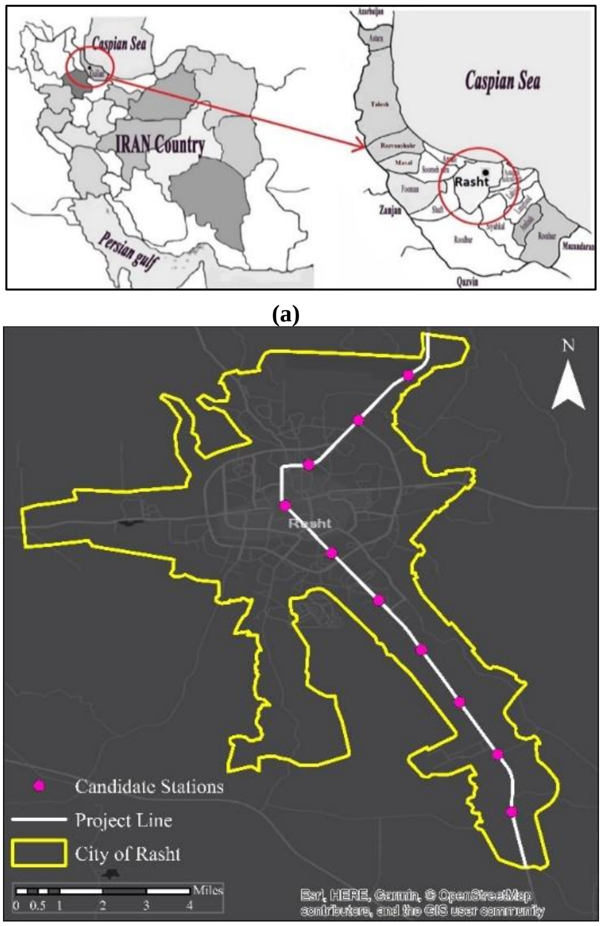
In the literature, there are several studies using multiple-criteria decision making for related site selection problems [15-17]. For example, Guo et al. [18] applied a fuzzy TOPSIS method to select optimal electric vehicle charging station (EVCS) sites. In another study, Ballis [19] implemented the Analytic Hierarchy Process (AHP) for solving the airport site selection problem at the island of Samothraki in Greece, which considers several significant criteria for airport site selection. Moreover, some research has combined Data Envelopment Analysis (DEA) with the Analytic Hierarchy Process (AHP) for site selection problems. For example, Mohajeri et al. [13] implemented a DEA method with AHP to find the best sites for a railway station in the city of Mashhad, Iran.

More broadly, several studies have used GIS-based multi-criteria decision-making (MCDM) methods for site selection problems [20-23]. For instance, Erbas et al [24] conducted a GIS-based fuzzy AHP with the combination of TOPSIS to select the optimal EVCS locations in the capital city of Turkey (Ankara). Rahmat et al. [25] applied a combination of AHP with GIS to find the land suitability for landfill sites in Behbahan, Iran. Furthermore, Al-Garni et al. implemented a GIS-AHP approach for a solar PV power plant site selection problem in Saudi Arabia [26]. Literature also shows that applying MCDM techniques and GIS is also useful to find the optimum sites of fire stations [27, 28]. For instance, Chaudhary et al. [29] used the AHP in the GIS interface to provide the fire station suitability zonation map in order to construct the new fire stations in Kathmandu City, Nepal.

As such, using GIS-based multi-criteria decision-making approaches could be useful for locating urban transportation facilities as well. For instance, Kabak [30] considered several criteria to find the location of future bike-share stations in Izmir, Turkey. In the current study, a GIS-based multi-criteria decision-making approach with the integration of the Analytic Hierarchy Process (AHP) and considering several conflicting factors is pursued to determine the top five subway station locations among the ten potential alternatives which recommended by the Traffic and Transportation Agency for a planned future mass transit system in the City of Rasht, Iran, and to help alleviate congestion-related problems. Thus, this paper is organized as follows: Section 2 presents the study area and the potential subway stations along the subway line. Section 3 describes the identification of pertinent criteria and sub-criteria and mapping them based on the study goal. Moreover, it explains the application of AHP in the current study in order to obtain the weights of each criterion and alternatives. Section 4 presents the results of previous stages and shows the priorities of criteria and subway stations along the subway line. Finally, Section 5 presents our conclusions, limitations of the current study, and future research opportunities.

2. Study Area

Rasht, with the highest population and urbanization rate in Gilan Province, is the largest city on the Caspian Sea coast of Iran. The illustration of the study area is shown in Figure 1 (a) [31]. Streets radiate from the center of the city through ring-shaped roadways, which gives a high level of importance to the city center. This, in turn, causes heavy congestion since the main retail, shopping, and business activities are located at the core of the city [32]. In order to alleviate this congestion, the Traffic and Transportation Agency of Rasht recently has proposed a northbound-southbound subway project line. This agency intends to establish five subway stations along this proposed project line to reduce traffic congestion in the City of Rasht. Therefore, the aim of this study is to find the best five stations among the ten proposed potential sites by the Traffic and Transportation Agency along the subway line. Figure 1(b) shows the location of these candidate subway stations in the study area.



(b)

Figure 1. (a) Location of the study area in the north of Iran; **(b)** An overview of candidate subway stations

3. Methodology

As stated in the previous sections, the Traffic and Transportation Agency of Rasht intends to construct five subway station sites along the proposed northbound-southbound subway project line for a future mass transit system in this city. For this purpose, a three steps model is applied in this study to determine the best five subway stations among the ten proposed locations by the Traffic and Transportation Agency along the subway line. The three steps are as follows: (1) Criteria identification based on the study goal; (2) Data collection and GIS maps preparation; and (3) Applying the AHP and calculation of criteria, sub-criteria, and alternatives weights. All these three steps will be explained in detail in the following subsections.

At the first step of this model, the suitability criteria and related sub-criteria are identified based on the 2011 comprehensive transportation planning study prepared by the Traffic and Transportation Agency of Rasht [33], other world standards/principles obtained through the literature [8, 13, 19, 25], and field observations.

In the second stage, after the identification of criteria, the geographic information of each criterion is mapped using ArcGIS software. Using the standard questionnaire survey [34] the instrument was sent to thirty experts in the transportation and traffic engineering, structural engineering, geotechnical engineering, and water resources engineering fields regarding the problem constraints such as traffic and transportation (population density, proximity to transit hubs, proximity to intersections), urbanism and economics (accessibility to hospitals and medical centers, land value, proximity to historical places), and engineering (soil type, impacts from earthquake faults, distance to rivers). Note that the experts were asked to fill the questionnaires that consist of a pairwise comparison of the main criteria, sub-criteria, and ten potential subway stations.

In the third stage, in order to implement the AHP to obtain the weights of criteria and candidate alternatives, the Expert Choice software is applied. Expert Choice is a decision support software that converts complex decision problems with multiple conflicting factors into a series of pairwise comparisons and it is compatible with the AHP method [35, 36]. Therefore, all the numerical data from the respondents are gathered and the average values for the criteria and sub-criteria are inserted into the pairwise comparison matrix using the Expert Choice software in order to obtain the weights of criteria, sub-criteria with respect to the main criteria, and candidate subway stations. Finally, the normalized weights of candidate sites are ranked to determine the best five subway stations among the ten potential sites in the study area. The conceptual flowchart of the analytical hierarchy model for the subway station problem is shown in Figure 2.

3.1. Criteria Identification

In this study, we have selected the three main criteria as the most significant factors as follows: transportation and traffic, urbanism and economics, and engineering. In addition to these main criteria, three sub-criteria are considered for each of the main criteria to find the best five subway stations among the candidate ones. As discussed in the previous section, the main criteria and sub-criteria used to select the subway station sites are based on the 2011 comprehensive transportation planning study of Rasht, other world standards and factors related to subway station site selection which were obtained through the literature, and field observations. Figure 3 shows the main criteria and the pertinent sub-criteria which have been considered.

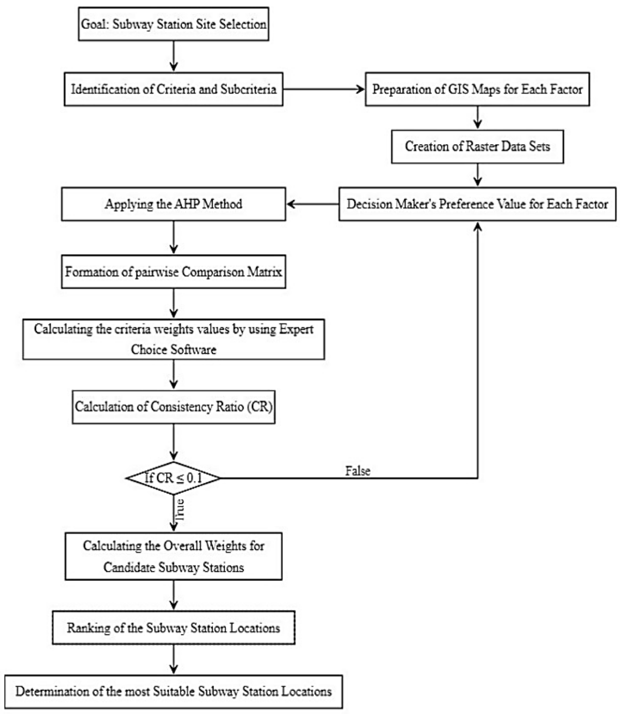


Figure 2. The conceptual flow of the research methodology

3.2. Data Collection and GIS Maps Preparation

The process of data collection involves two main stages. The first stage includes the data which has been obtained from different organizations and companies, and the second one includes the data which has been collected by GPS in the field. The data regarding population density, river locations, earthquake faults, soil type, and land value were acquired from the 2011 comprehensive transportation planning study, the municipality of Rasht, traffic and transportation agency of Rasht, and Andishkar Consulting Engineers Company [33]. The data regarding ancient and historical places was obtained from Gilan's Cultural Heritage, Handicrafts and Tourism Organization [37]. Finally, the coordinates of existing bus and taxi stations, intersections locations and hospitals and medical centers were established based on GPS, and then they were converted to shapefiles to be managed in a GIS environment.

In the next step, for each of the nine factors a separate layer is created and then all GIS layers were converted to a raster format. Rasterization is a process in which all the objects present in an area are transformed from vector form to the raster one and the value of each pixel is determined. Among the functions available for rasterizing, Euclidean Distance is one of the most important functions for rasterizing the range of objects and the study area. Indeed, this function calculates the direct distance from the center of each pixel to the center of the object's pixel and allocates this calculated distance to each pixel [38]. In the following section, the rasterized format of the input map layers is shown.

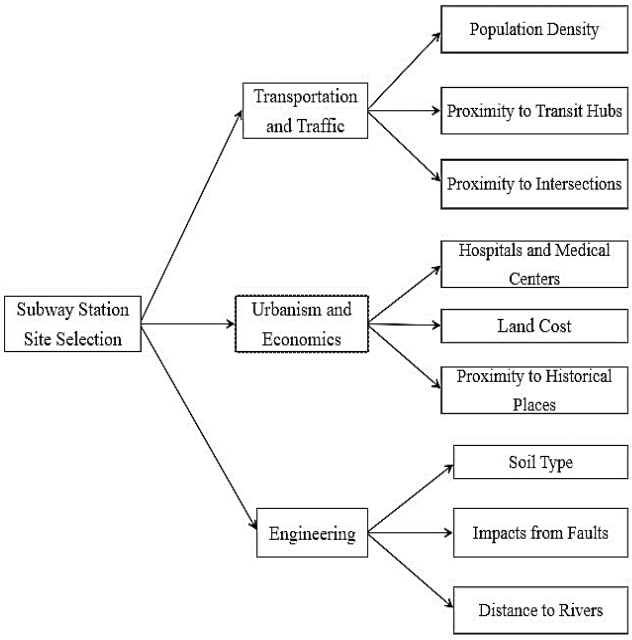


Figure 3. Criteria and sub-criteria for the subway station site selection

3.2.1. Population Density

Population density is one of the most important factors for subway station site selection. Based on the acquired data the population density map is provided. As can be seen in Figure 4 (a), the north and a small portion of southern regions of the city of Rasht can be identified as being denser in population in comparison to other areas.

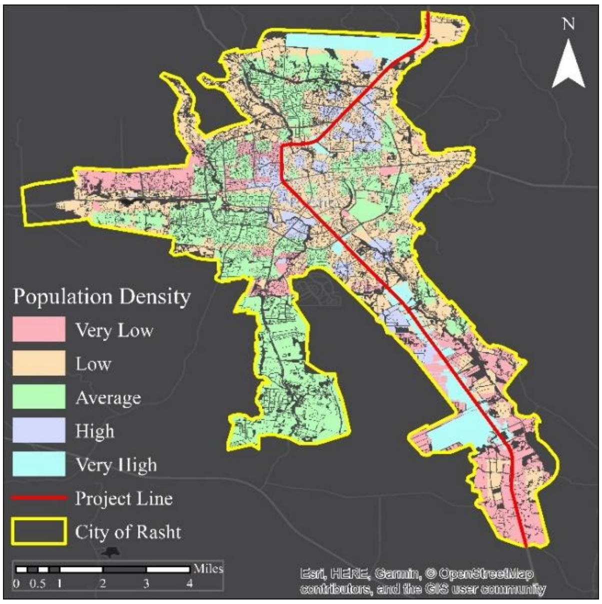


Figure 4 (a) Population density map of Rasht City

3.2.2. Proximity to Intersections

According to the established data on GPS, the thematic map of available intersections on the project line is created. As seen in Figure 4 (b), most of the intersections are in the mid- and northern regions of the study area. Hence, the stations which have been located in these areas are closer to the intersections.

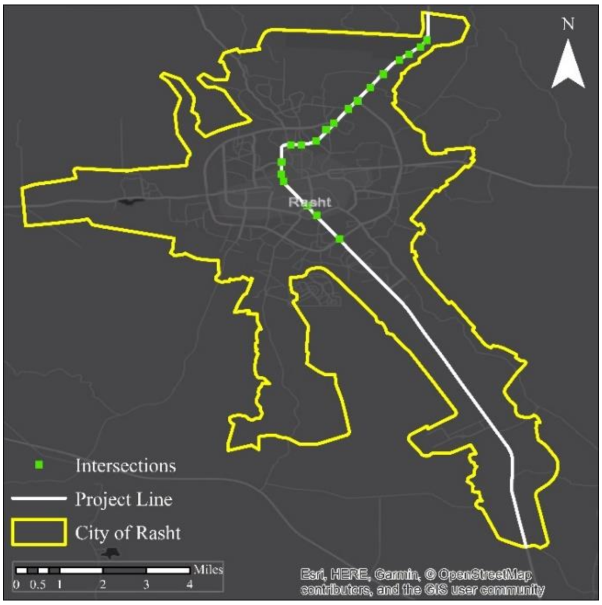


Figure 4 (b) Intersections locations map of the study area

3.2.3. Proximity to Transit Hubs

Access to transit hubs such as taxi and bus stations is one of the most important criteria regarding the subway station location. Similar to the intersection's locations, most of the transit hubs are in the center and northern regions of the city. The corresponding figure for the existing bus and taxi stations is as follows (Figure 4 (c)).

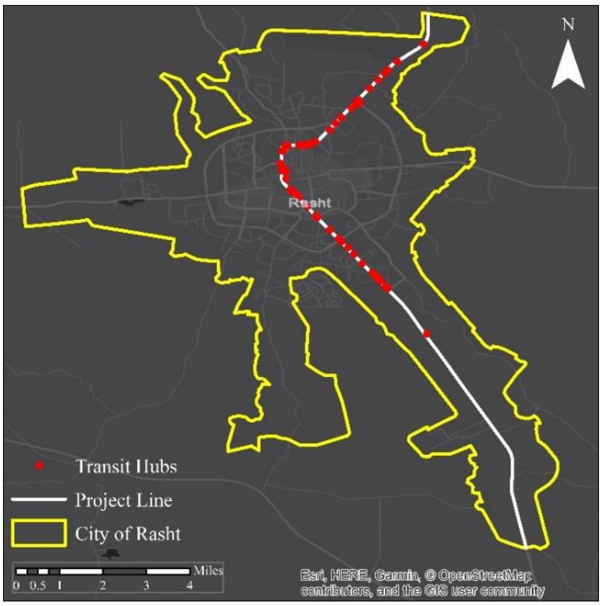


Figure 4 (c) Transit hubs stations map of the study area

3.2.4. Hospitals and Medical Centers

Hospitals and medical centers can also be considered as another important parameter for subway station locations since their accessibility is critical. Based on the input information, a digital thematic map is derived. According to Figure 4 (d), most of these hospitals and medical centers have been located in the center of the city. Therefore, the subway stations which are in the middle of the project line are closer to these facilities.

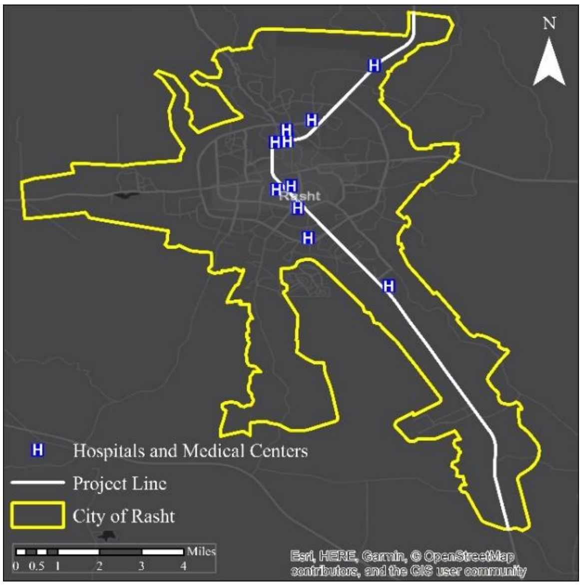


Figure 4 (d) Hospitals and medical centers locations map of the study area

3.2.5. Historical Places

Accessibility to historical and archaeological places is another important factor for subway station site selection. Similar to previous factors a thematic map of historical places is derived. As seen from Figure 4 (e), all the historical places have been located in the center region of the city and it can be concluded that the stations are in the middle of the subway line are close to these places.

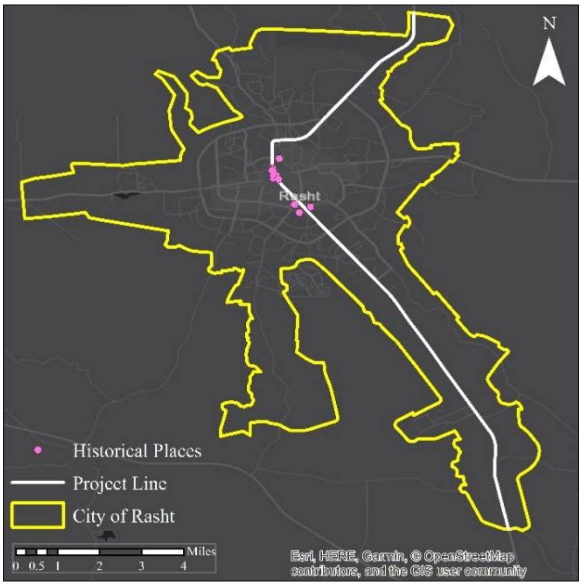


Figure 4 (e) Historical places map of study area

3.2.6. Land Value

Land value is another important factor that has been considered in this study. Based on the acquired data from the 2011 comprehensive transportation planning study and the Traffic and Transportation Agency of Rasht, a thematic map of land value in the city of Rasht is obtained. It can be seen in Figure 4 (f) that most sections of the project line have medium values; however, the northern and southern parts of the project line have very low values.

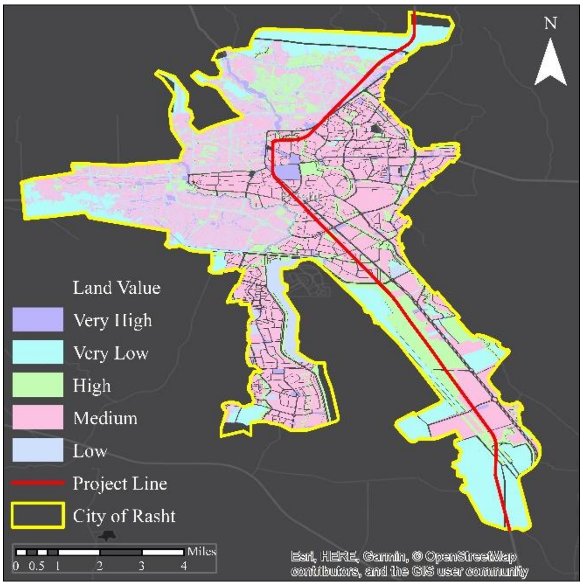


Figure 4 (f) Land value map of the study area

3.2.7. Distance to Rivers

River presence is another important factor for subway station location and there are two major rivers in the city of Rasht. As such, a digital thematic map of the rivers is derived by using the Euclidian distance method. As seen from Figure 4 (g), the river which is on the western part of the city didn't cross the project line. However, the other river has crossed the project line in three points.

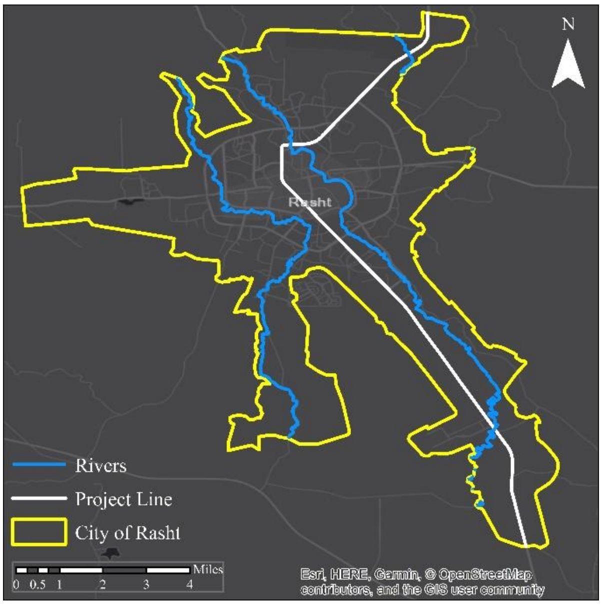


Figure 4 (g) Rivers map of study area

3.2.8. Impact of Earthquake Faults

Based on the acquired information from the municipality of Rasht, Traffic and Transportation Agency of Rasht, fortunately, there is no fault line in the study area, and it does not affect the subway station site selection. Therefore, this factor can be considered a neutral criterion with the same rating value for all the criteria. In other words, this criterion has a value equal to 1 for all candidate subway stations.

3.2.9. Soil Type

Based on the Traffic and Transportation Agency of Rasht report, soil type is classified as seven different types in the city of Rasht. According to Figure 4 (h), it can be concluded that most of the project line has been located in the soil type as clay with moderate resistance. The other parts of it are gravel with high and moderate density silty clay and clay with moderate density.

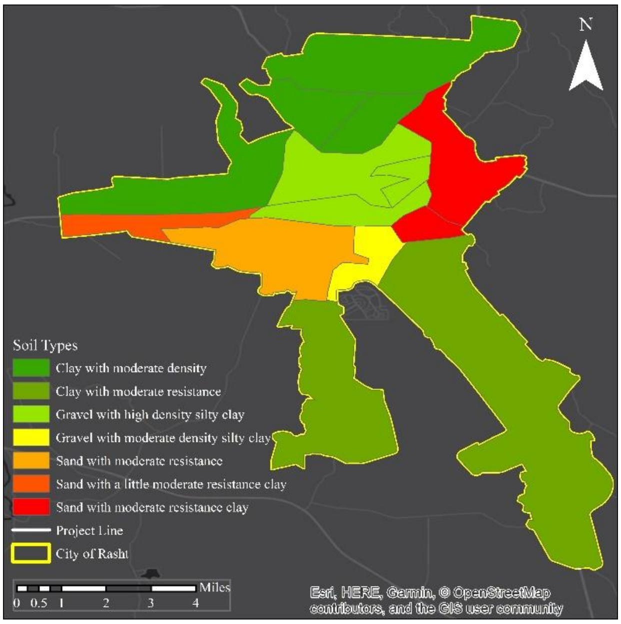


Figure 4 (h) Soil type map of study area

3.3. Analytic Hierarchy Process (AHP) Methodology

The AHP, as defined by Saaty [39, 40], is one of the multi-criteria decision-making methods, which basically converts a complicated problem into a hierarchy with respect to different criteria and sub-criteria. In order to understand the relative importance of each evaluation criterion, the AHP generates a weight for each of the criteria and sub-criteria based on the experts and decision maker's pairwise comparison. The higher the weight, the more important the corresponding criterion. The comparison between factors is measured based on a numerical scale from 1 to 9, as shown in Table 1. The upper and lower triangle of the pairwise comparison matrix is based on the average values of questionnaires which were filled by experts and the diagonal elements of this matrix are 1 [41, 42]. In the final stage, the numerical priorities of the alternatives are calculated based on the obtained weights. The pairwise comparison matrix A is as Eq. (1)

$$\boldsymbol{A} = [\boldsymbol{a_{ij}}] = \begin{bmatrix} \boldsymbol{a_{11}} & \boldsymbol{a_{12}} & \cdots & \boldsymbol{a_{1n}} \\ \vdots & \vdots & & \vdots \\ \boldsymbol{a_{n1}} & \boldsymbol{a_{n2}} & \cdots & \boldsymbol{a_{nn}} \end{bmatrix} \quad (1)$$

Table 1. Saaty's pairwise comparison scale

Numeric Value	Verbal Judgment
1	Equally important
2	Equally to moderately more important
3	Moderately more important
4	Moderately to strongly more important
5	Strongly more important
6	Strongly to very strongly more important
7	Very strongly more important
8	Very strongly to extremely more important
9	Extremely more important
Reciprocals	Used for inverse comparison

The numeric values are based on the decision-makers' opinion, and it is possible to have some inconsistencies in the matrix. In order to avoid this inconsistency, the AHP calculates the Consistency Ratio (CR). Consistency Ratio (CR) is calculated by dividing the Consistency Index (CI) over the Randomized Index (RI) to calculate the overall consistency. Saaty [39, 40] has shown that if the value of CR is smaller or equal to 10% ($CR < 0.1$), the pairwise comparisons are acceptable. If $CR \geq 0.1$, on the other hand, the value shows the inconsistent judgments and pairwise comparison matrix is needed to be revised. Saaty [39, 40] provides the RI values for matrices of different sizes. Table 2 shows the RI values for the pairwise comparison matrices. The Consistency Index (CI) can be calculated based on the Eq. (2)

$$\boldsymbol{CI} = \frac{\boldsymbol{\lambda_{max} - n}}{\boldsymbol{n-1}} \quad (2)$$

where λ_{max} is the maximum eigenvalue of the preference matrix and n is the order of the comparison matrix. λ_{max} can be obtained using the Eq. (3)

$$\boldsymbol{Aw} = \boldsymbol{\lambda_{max} w} \quad (3)$$

where $w = (w_1, \ldots, w_n)$ is the corresponding eigenvector of A. Finally, the Consistency Ratio (CR) is defined as Eq. (4)

$$CR = \frac{\boldsymbol{CI}}{\boldsymbol{RI}} \quad (4)$$

Table 2. Random consistency index (RI) for pairwise comparison

N	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

4. Results and Discussions

As discussed in the previous sections, we aim to find the best five subway station locations among the ten candidate ones along the proposed northbound-southbound subway line which were recommended by the Traffic and Transportation Agency of Rasht by implementing GIS-based AHP on the considered criteria and sub-criteria. Table 3 shows the average values of the experts' judgments and corresponding weights of the main criteria and normalized relative weights of them based on the comparison matrix. Furthermore, Tables 4, 5, and 6 illustrate the priorities of sub-criteria with respect to the corresponding main criteria including transportation and traffic, urbanism and economics, and engineering, respectively. As seen from the tables, the inconsistency of all comparisons is less than 0.1, and it can be concluded that obtained priorities are reliable. According to Table 3, the transportation and traffic criterion, with a weight equal to 0.648, has the highest importance in comparison to the other criteria. Moreover, the urbanism and economics sub-criterion is ranked second, and it has higher importance than the engineering criterion.

Table 3. Pair wise comparison matrix of the main criteria with respect to goal

Criteria	Transportation and Traffic	Urbanism and Economics	Engineering	Importance Weight	Normalized Relative Weights
Transportation and Traffic	1	3	5	0.648	1
Urbanism and Economics	1/3	1	2	0.230	0.354
Engineering	1/5	1/2	1	0.122	0.188
Inconsistency = 0.00352					

According to Table 4, the sub-criterion population density has the highest weight (0.614) among the other transportation and traffic sub-criteria. The proximity to transit hubs with the weight equal to 0.268 is in the second rank. Finally, the proximity to intersections is the least important sub-criterion among transportation and traffic sub-criteria.

Table 4. Pairwise comparison matrix for the sub-criteria with respect to transportation and traffic

Sub-Criteria	Population Density	Proximity to Intersections	Proximity to Transit Hubs	Priorities Weights	Normalized Relative Weights
Population Density	1	4	3	0.614	1
Proximity to Intersections	1/4	1	1/3	0.117	0.191
Proximity to Transit Hubs	1/3	3	1	0.268	0.437
Inconsistency = 0.07					

From Table 5, we observe that the hospitals and medical centers sub-criterion has the highest value (0.493) than the other sub-criteria of urbanism and economics criterion. The land value with the weight value of 0.311 is the second sub-criterion and the proximity to historical places ranks third among the sub-criteria. The priorities weights along with the normalized relative weights of all sub-criteria are as follows:

Table 5. Pairwise comparison matrix for the sub-criteria with respect to urbanism and economics

Sub-Criteria	Hospitals and Medical Centers	Proximity to Historical Places	Land Value	Priorities Weights	Normalized Relative Weights
Hospitals and Medical Centers	1	2	2	0.493	1
Proximity to Historical Places	1/2	1	1/2	0.196	0.397
Land Value	1/2	2	1	0.311	0.630
Inconsistency = 0.05					

The soil type sub-criterion, with the highest weight, which is equal to 0.540, is the most important factor among the sub-criteria of engineering criterion. Distance to rivers (0.297) and impacts from earthquake faults (0.163) rank second and third, respectively. Table 6 shows the results of engineering sub-criteria obtained by average values in which the questionnaires were filled by the experts.

Table 6. Pairwise comparison matrix for the sub-criteria with respect to engineering

Sub-Criteria	Distance to Rivers	Impacts from Earthquake Faults	Soil Type	Priorities Weights	Normalized Relative Weights
Distance to Rivers	1	2	1/2	0.297	0.550
Impacts from Earthquake Faults	1/2	1	1/3	0.163	0.303
Soil Type	2	3	1	0.540	1
Inconsistency = 0.008					

Tables 7, 8, and 9 show the corresponding weights of the ten candidate subway stations with respect to the main criteria. As seen from Table 7, stations numbers 9, 8, 7, 3, and 6 have higher values than the other candidate stations with respect to transportation and traffic criterion. Thus, in terms of population density, accessibility to transit hubs such as taxi and bus stations, and proximity to intersections these stations are the best five subway stations among the candidate alternatives.

Table 7. Pairwise comparison matrix for the alternatives with respect to transportation and traffic

Criterion	Candidate Subway Stations	Overall Weights
Transportation and Traffic	Station 1	0.041
	Station 2	0.040
	Station 3	0.126
	Station 4	0.079
	Station 5	0.083
	Station 6	0.117
	Station 7	0.128
	Station 8	0.139
	Station 9	0.181
Overall Inconsistency = 0.05	Station 10	0.065

Regarding the urbanism and economics criterion, Table 8 shows that the stations 8, 6, 7, 9, and 10 have the highest overall weights among the ten candidate subway stations. Therefore, these stations are more accessible to hospitals and medical centers and historical places. Furthermore, in terms of constructing a new station with respect to the land price, these stations rank higher than other ones.

Table 8. Pairwise comparison matrix for the alternatives with respect to urbanism and economics

Criterion	Candidate Subway Stations	Overall Weights
Urbanism and Economics	Station 1	0.094
	Station 2	0.094
	Station 3	0.066
	Station 4	0.051
	Station 5	0.076
	Station 6	0.141
	Station 7	0.116
	Station 8	0.154
	Station 9	0.112
Overall Inconsistency = 0.02	Station 10	0.095

Finally, based on the obtained results in Table 9, stations number 7, 6, 10, 1, and 8 have the highest values with respect to the engineering criterion in comparison to other candidate alternatives. In other words, these stations with regard to soil type and distance to rivers are the best five stations in the study area. Moreover, the impacts from the earthquake fault sub-criterion is equal for each subway station, and it does not affect the overall weights for the candidate stations.

According to the obtained results, the station 9 (0.156), station 8 (0.136), station 7 (0.126), station 6 (0.118) and, station 3 (0.109) have the highest importance weights among the ten candidate stations and are the most important stations, respectively. Hence, they can be selected as the best five subway stations along the proposed northbound-southbound subway line for the future mass transit system in the City of Rasht. Figure 5 shows the location of these subway stations in the study area.

Table 9. Pairwise comparison matrix for the alternatives with respect to engineering

Criterion	Candidate Subway Stations	Overall Weights
Engineering	Station 1	0.112
	Station 2	0.091
	Station 3	0.062
	Station 4	0.078
	Station 5	0.073
	Station 6	0.120
	Station 7	0.171
	Station 8	0.094
Overall Inconsistency = 0.01	Station 9	0.082
	Station 10	0.117

In the next step, the final values of the candidate alternatives are obtained, and they are ranked based on their weights. Table 10 summarizes these values for the candidate subway stations with the consideration of the study goal and shows the priorities of them.

Table 10. Importance weights of candidate subway stations

Candidate Subway Stations	Final Values
Station 9	0.153
Station 8	0.137
Station 7	0.131
Station 6	0.123
Station 3	0.104
Station 5	0.080
Station 10	0.078
Station 4	0.073
Station 1	0.062
Station 2	0.059
Overall Inconsistency = 0.03	

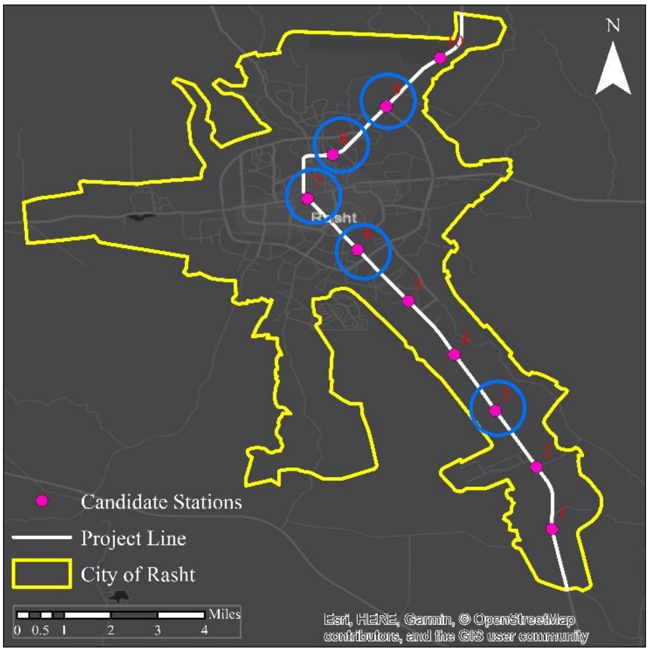


Figure 5. Location of the best five subway stations along the project line

5. Conclusions and Future Work

In this paper, we evaluated the problem of establishing five optimal subway stations along a proposed northbound-southbound subway line in the City of Rasht, Iran. For this purpose, a GIS-based multi-criteria decision approach with the combination of the Analytic Hierarchy Process (AHP) was adopted in this study to assess and obtain the best five locations of subway stations among the ten candidate sites which were recommended by the Traffic and Transportation Agency of Rasht for a planned future mass transit system in this city. In order to achieve this, we have considered three main criteria (transportation and traffic, urbanism and economics, and engineering) and nine other sub-criteria in this study. The data were obtained through multiple governmental and local company resources. After preparing the factors in the form of information layers, the geographical objects were rasterized, and GIS maps were prepared. In order to apply the AHP, a standard questionnaire survey was conducted to obtain the average values of all criteria and sub-criteria to form the matrices in the Expert Choice software. The questionnaires were filled by decision-makers in the area of transportation and traffic engineering, structural engineering, geotechnical engineering, and water resources engineering. Then, the relative importance of criteria and sub-criteria were obtained based on their weights. The results showed that the transportation and traffic criterion was the most important one among the main criteria. Moreover, population density, accessibility to hospitals and medical centers, and soil type factors had the highest importance weight among the other sub-criteria with respect to transportation and traffic, urbanism and economics, and engineering criteria, respectively. Finally, the candidate subway stations were ranked based on the overall weights and the results showed that the Stations 9, 8, 7, 6, and 3 were the optimal five subway stations along the proposed subway line in the City of Rasht. This approach can provide useful insights for the traffic and transportation agencies that are dealing with site selection and urban planning problems specifically in developing countries.

In terms of limitations, this study considers three main criteria; however, involving more criteria in the decision process such as environmental factors can be critical. Other criteria such as accessibility to bike users, land cover, and land possession can also be added to the model as a part of future research. Moreover, this study only focused on the City of Rasht; however, future work also can be extended to other locations given the data availability. Finally, expanding this type of methodology by using different MCDM methods could be another possible improvement in the context of the site selection problem.

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