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ORIGINAL ARTICLE

Possess of locating the elementary schools using combined FAHP-Fuzzy logic in the GIS

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According to population growth and consequently students growth and on the other hand lack of educational spaces, imbalance in supply (students) and demand (educational centers), it causes high population density of students in classrooms, beyond standards. In addition, imbalanced population density causes accessibility problems to these centers and also spending a lot of students' time and money. The mentioned problems are due to weaknesses in the construction of schools in appropriate locations. Lots of urban dilemmas such as traffic, pollution, Social and cultural issues and security can reduce by choosing appropriate location for construction of schools. There are different methods for determining the appropriate locations for the construction of schools, among which the most important is the hierarchical process analysis method. In this study, using Fuzzy logic in the geographical information system (GIS), space Distribution and Location of deployment and Functional radius of the elementary schools in the Qazvin city have investigated and also in the network analysis method, areas out of schools coverage have been specified. Then, using Fuzzy Analytical Hierarchy Process, layers, criteria and also effective sub-criteria in choosing location of elementary schools, weighted and combined each other and appropriate and inappropriate locations for construction of elementary schools, especially in areas that placed out of schools coverage, have obtained. Results show that the elementary schools of the Qazvin city aren't enough for covering all of the total area, and some of the northern, eastern and western neighborhoods despite having the necessary student density, are deprived of having elementary school and also are out of the coverage of existing schools.
Key words: locating of schools; fuzzy logic; FAHP; Qazvin city

Rapid growth of urbanization phenomenon in under developing countries has created major social, economic and physical problems. Considering the growth of Qazvin's population in recent years, consequently the growth of the student population and on the other hand lack of educational spaces, imbalance in supply (students) and demand (educational centers) clearly seen. High student density in the classrooms beyond exist standards and also density of educational spaces in certain parts of the city, quality of educational centers and etc. cause problems of access to these centers and spend time and money of the students. In the world and also in our country researches has been done on techniques and methods of locating, some of which will be discussed.

Nelio et al. (2004) in a study considering the criteria such as geology, fault, slope, centers of the population, and using the weighting system of criteria, proposed places for the construction of schools. Laleh poor investigated the use of land in urban planning using the GIS and concluded that the status of elementary schools in 8th region of Tehran in terms of criteria and condition that should be followed in the elementary schools locating isn't in proper condition (Lalehpoor, 2002). Farhadi analyzed the spatial distribution of schools using GIS (Farhadi, 2000). His research results point to the capabilities of this system in locating of schools and emphasize on distance factor and population. Amanpoor and Asakare studied on evaluating, locating and providing an optimal model for locating educational use, especially in Shadegan elementary schools and investigated the status of these schools in terms of locating criteria for educational centers using GIS (Amanpoor, 2014). Results of this study indicate that the elementary schools in Shadegan aren't suitable in terms of considered criteria. Ahadnejad conducted an

investigation entitled "Analysis of Spatial Dispersion Pattern of Educational Centers and arranging its skeletal using GIS" in eight regions of Tabriz (Ahadnejad, 2012). The results of this study reveal imbalanced distribution of these centers in the region. Also the location of new centers was done by implementing the TOPSIS method in the GIS software.
As the background study shows, research on the use of "GIS" in combination with multi-criteria decision making models, mostly tries to introducing the "GIS" functionality as an effective tool for organizing training centers, and using more efficient models and optimizing the issue of deployment of educational centers using innovative methods such as Fuzzy logic in combination with "GIS" and also Using Fuzzy Hierarchical Technique for weighting, less attention has been paid.

Introduction of the study region

Qazvin is one of the cities in the west of Iran and the center of Qazvin province. The city is situated at an altitude of 1278 meters above sea level, 50 degrees east longitude and 16.36 degrees north latitude. Qazvin extends from the north east to Razmian, from the east of Bidestan and Mohammadieh, from the south east to Alvand, from the south west to Aqbalia, from the west to Mahmoodabad, and from the northwest to Manjil (Fig. 1).

Fig. 1. Geographical location of Qazvin city (from https://www.worldatlas.com/img/locator/city/039/11539-qazvin-locator-map.jpg)

Research Methodology

This research is an applied analytical method used the fuzzy logic combined with the process of analyzing the fuzzy hierarchy for locating elementary schools in Qazvin city. Layers and standards affecting the establishment of schools were identified and questionnaires and opinion polls by their respective experts were prioritized using fuzzy hierarchy analysis weighting method. Then, a map of suitable places for the construction of new schools in Qazvin was presented by combining these layers. In relation to the location of the educational services (schools), four basic criteria are considered, each of which in turn has the sub-criteria, as described below (Fig. 2).
Compatibility and incompatibility: the component of compatibility is the placement of compatible uses together and vice versa separating maladaptive uses (Ziari, 2010),
Capacity: location capacity is a major factor determining the levels of use for the physical volume of education (Salehi, 2010).
Access radius: in this method, to obtain the elementary schools level of service, the maximum time that a student goes to school through the network is considered. Standard access radius for an elementary student on foot is 15 minutes or the maximum distance to a student's home that is 500 meters (Ghafari, 1998).

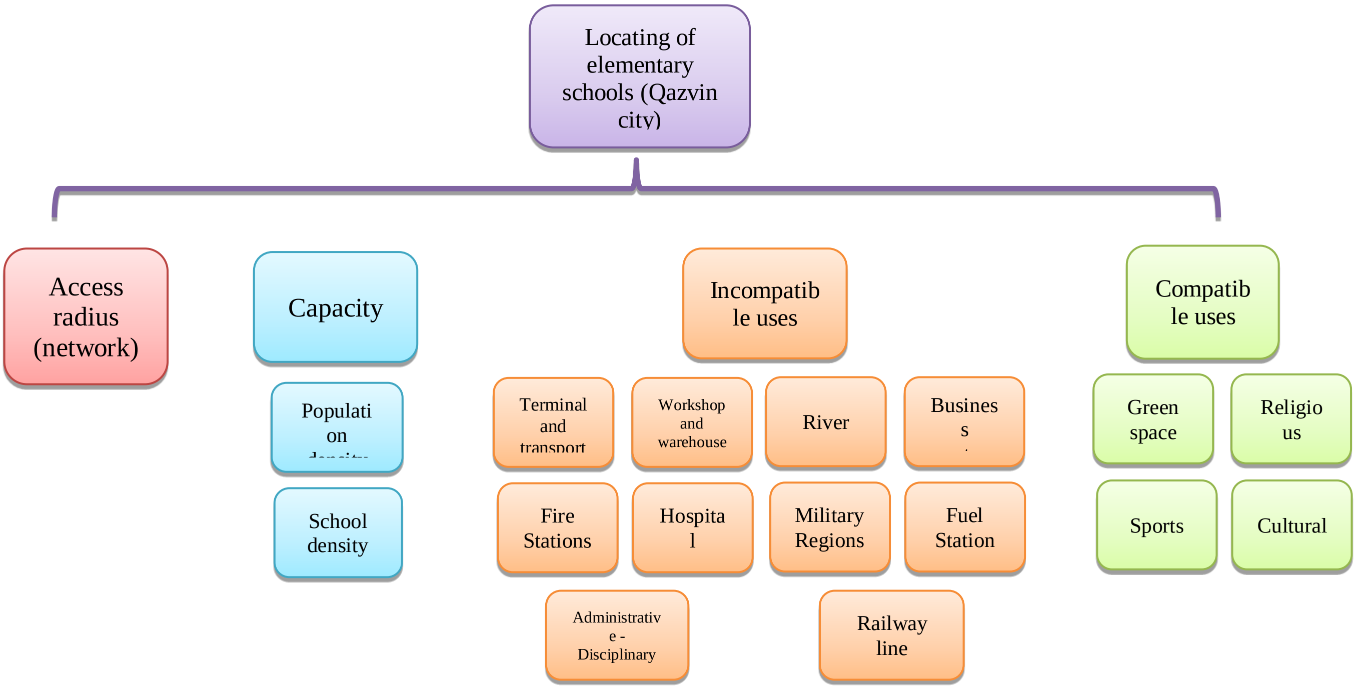


Fig. 2. Criteria and sub-criteria for locating elementary schools

Process of fuzzy hierarchy analysis.

The steps of the fuzzy hierarchical analysis method based on Chang's method as follow:

Step 1; Draw the hierarchical tree:

The structure of the decision hierarchy is drawn using the target, criterion and option levels.

Step 2; Formation of paired comparison matrix:

Using the decision maker's viewpoint, the comparison matrix with use of triangular fuzzy numbers is based on the views of several decision makers is formed (Li & Yeh, 2005).

$$\tilde{A} = \begin{bmatrix} (1,1,1) & \tilde{a}_{12} & \tilde{a}_{1n} \\ \tilde{a}_{21} & (1,1,1) & \tilde{a}_{2n} \\ \vdots & \vdots & \vdots \\ \tilde{a}_{n1} & \tilde{a}_{n2} & (1,1,1) \end{bmatrix}$$

Fuzzy Judgment Matrix:

In this matrix, p_{ij} is the number of $\tilde{t}_{ij} = (a_{ij}, b_{ij}, c_{ij})$ commentators about the priority of element i to j.

Step 3; Arithmetic mean of the comments:

Arithmetic mean of the decision makers' comments calculates as the following matrix:

$$\tilde{a}_{ij} = \frac{\sum_{k=1}^{p_{ij}} a_{ijk}}{p_{ij}} \qquad i,j = 1,2,\dots,n$$

Eq. (1)

Step 4; Calculation the sum of the rows elements:

$$\tilde{s}_i = \sum_{j=1}^{n} \tilde{a}_{ij} \qquad i = 1,2,\dots,n$$

Eq. (2)

Step 5; Normalization:

The sum of the rows is normalized in the following way:

$$\tilde{M}_i = \tilde{s}_i \otimes \left[\sum_{i=1}^{n} \tilde{s}_i\right]^{-1} \qquad i = 1,2,\dots,n$$

Eq. (3)

$$\tilde{M}_i = \left(\frac{l_i}{\sum_{i=1}^{n} u_i}, \frac{m_i}{\sum_{i=1}^{n} m_i}, \frac{u_i}{\sum_{i=1}^{n} l_i}\right)$$

Eq. (4)

Step 6; determine the degree of greater probability:

The degree of grater probability of the each iµ is calculated relative to others (other iµ) and called d'(Ai).
The degree of greater probability of fuzzy triangle number µ2= (l2, m2, u2) relative to the fuzzy triangle number µ1= (l1, m1, u1) is equal to (Baudry et al., 2018; Sun et al., 2016):

$$V(M_2 > M_1) = \text{Sub}_{y \geq x}\left[min\left(\mu_{M_1}(x), \mu_{M_2}(y)\right)\right]$$ Eq. (5)

This equation can be expressed as follow:

$$V(M_2 \geq M_1) = hgt(M_2 \cap M_1) = \mu_{M_2}(d) = \begin{cases} 1 & \text{اگر } m_2 \geq m_1 \\ 0 & \text{اگر } l_2 \geq u_1 \\ \dfrac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)} & \text{در غیر اینصورت} \end{cases}$$ Eq. (6)

Where “d” are the coordinate of the highest point in the substation region and the collision of two membership functions(Celik, Gul, Aydin, Gumus, & Guneri, 2015).

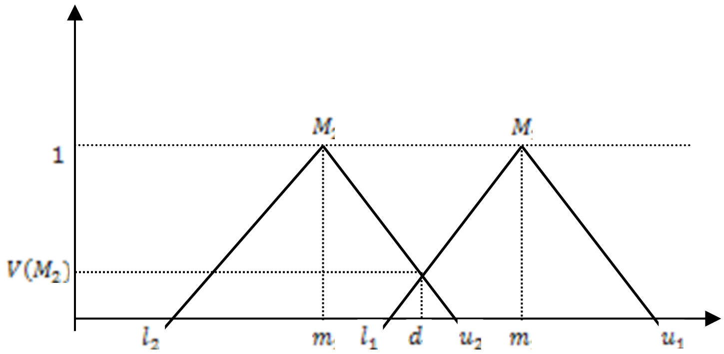


Fig. 3. Priority of two triangular fuzzy numbers

To compare M_1 and M_2, the calculation of both $V_{(M2 \geq M1)}$ and $V_{(M1 \geq M2)}$ is necessary.
The greater probability degree of a convex fuzzy number (M) from other K convex fuzzy numbers (MI; i = 1, 2, k) is broken down as follows (E. Taleai, 2010):

$$d'(M) = \min_{i=1,2,k} V(M \geq M_i) = V(M \geq M_1, M_2, \ldots, M_k) = V[(M \geq M_1), (M \geq M_2), \ldots, (M \geq M_k)]$$ Eq. (7)

Step 7; Normalization:
The normalized weights are obtained by normalizing the vector of weights (McMullin, 2000).

$$w = \left[\frac{d'(A_1)}{\sum_{i=1}^{n} d'(A_i)}, \frac{d'(A_2)}{\sum_{i=1}^{n} d'(A_i)}, \ldots, \frac{d'(A_n)}{\sum_{i=1}^{n} d'(A_n)}\right]^T$$ Eq. (8)

The above weights are definite (non-fuzzy). Weights of all matrices are obtained by repeating this process. By doing these calculations, the results are obtained as follows.

Step 8; Weight combinations:
The final weights are obtained by combination of the criteria and options weight (Sehatpour & Kazemi, 2018; Taleai, 2010; Taleai et al., 2009)

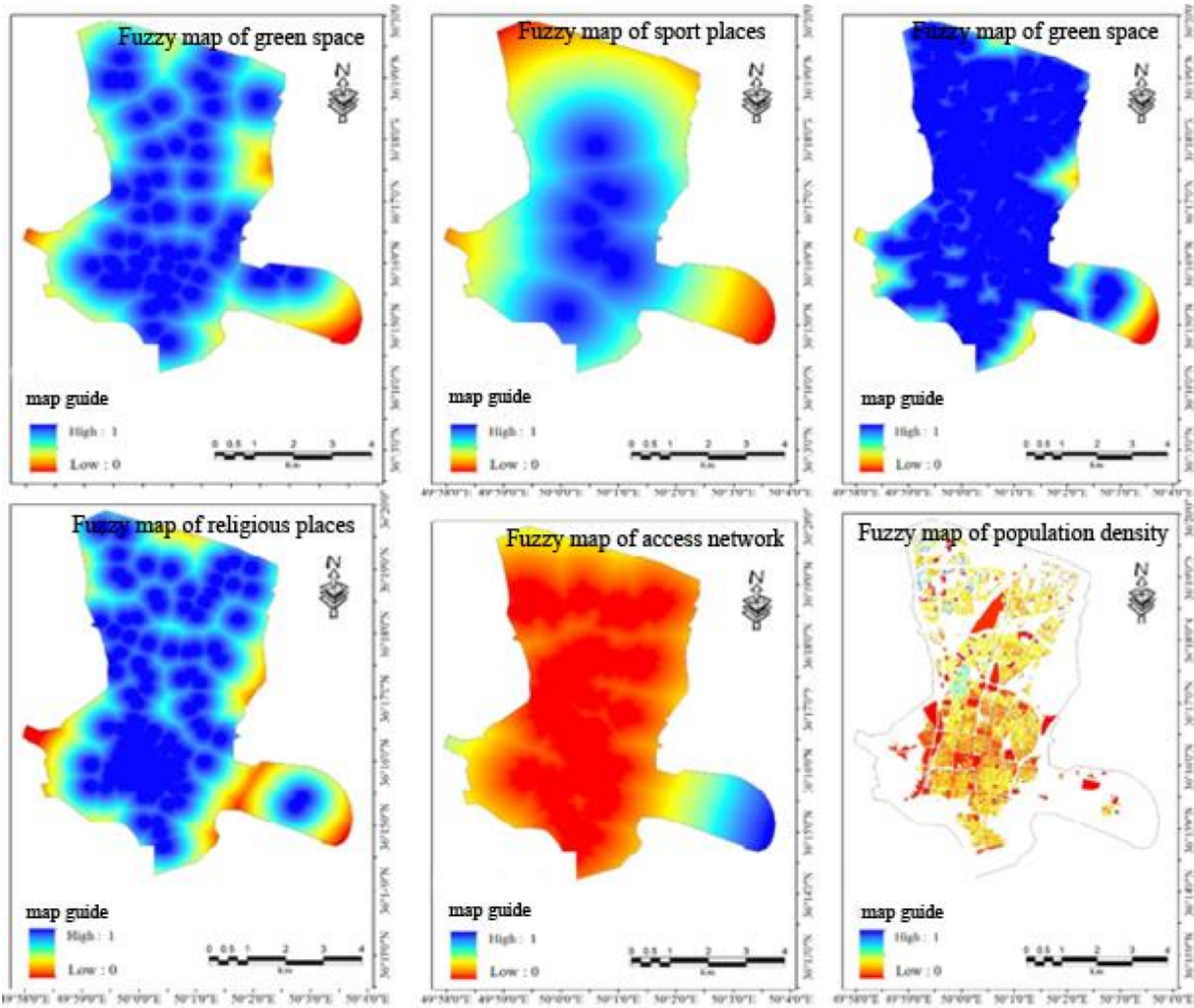
$$\tilde{U}_i = \sum_{j=1}^{n} \tilde{w}_i \tilde{r}_{ij} \qquad \forall i$$ Eq. (9)

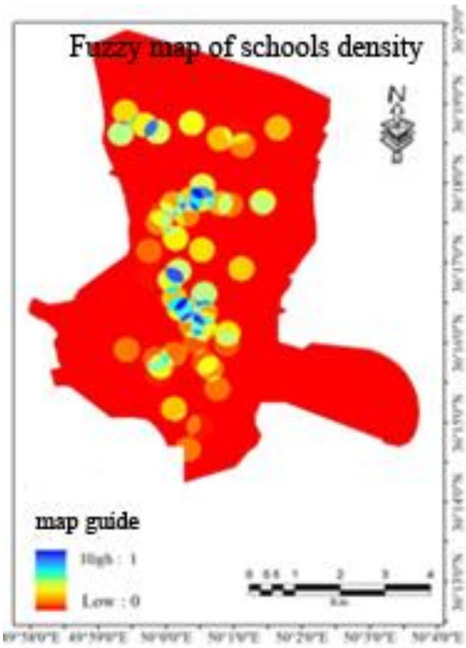
Rastering the layers

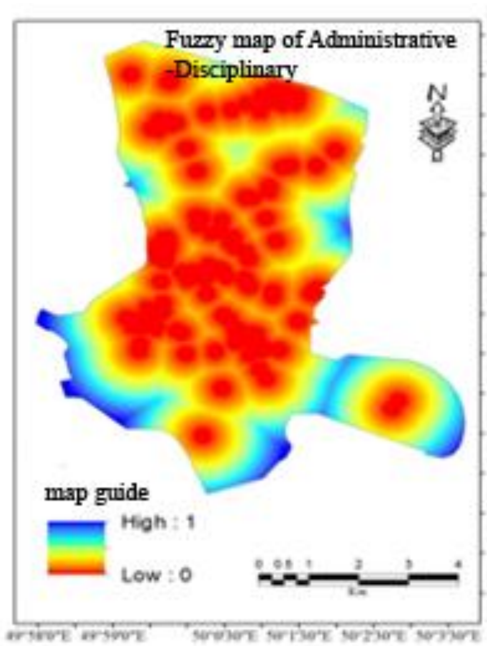
In this step, to standardize the layers, the criteria must be rastered before using fuzzy functions. Therefore, Euclidean Distance tools in the Arctic GIS software is used for rastering the layers. In the case of the population, Because more people will need more services, therefore population density was calculated taking into account the area and population parameters and using the formula E = P * 100 / d, in which E,P and d are equal to the population density, the population and the area, respectively. Then rastering the layers were done according to the density field.

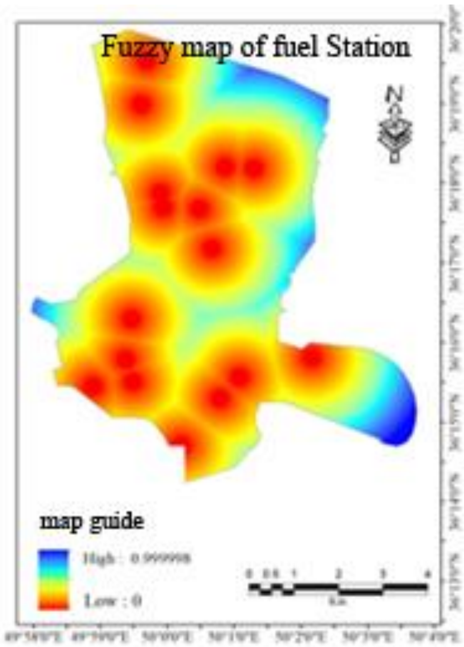
Fuzzing the layers

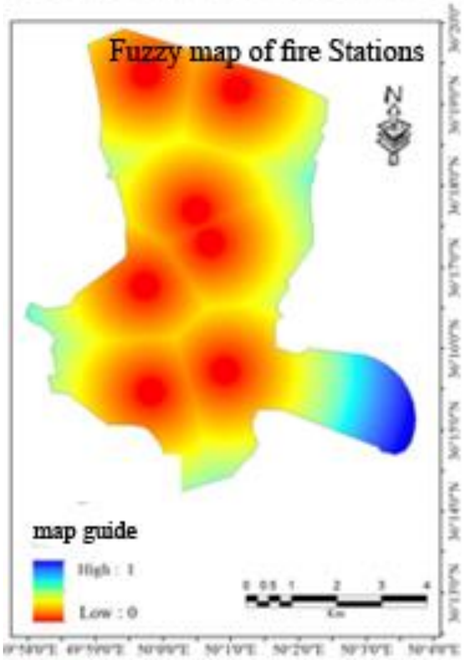
At this step, depending on the effect of each of the measures, the type of function for layers fuzzing was chosen. It should be noted that the new schools should be placed in the furthest distance of incompatible uses, in the densely populated area, out of area that existing schools services, and also close to compatible users and in a region with less density of schools. Therefore, in order to fuzzing the sub-criteria of incompatibility, the access radius of population, density and the density of schools, incremental linear function was used. The performance of this function is that the higher the map number, take greater value and vice versa. Also linear decrease function was used for the compatible layer. Normalized maps are given below (Fig.4).




Fuzzy map of schools density
N
map guide
High : 1
Low : 0


Fuzzy map of Administrative
-Disciplinary
N
map guide
High : 1
Low : 0


Fuzzy map of fuel Station
N
map guide
Low : 0


Fuzzy map of fire Stations
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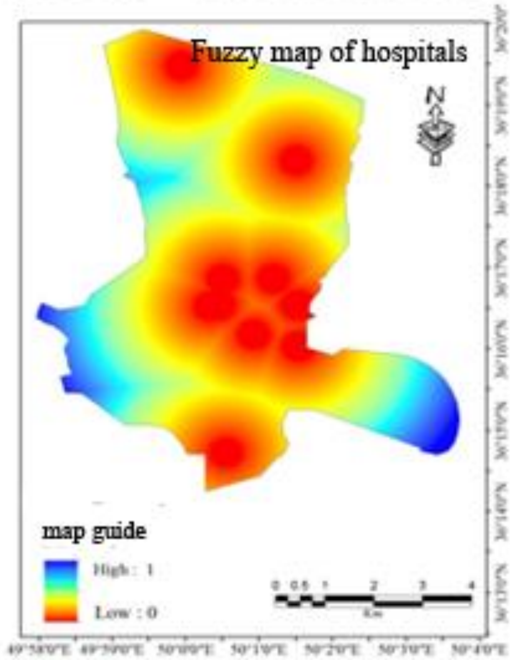
map guide
High : 1
Low : 0


Fuzzy map of hospitals
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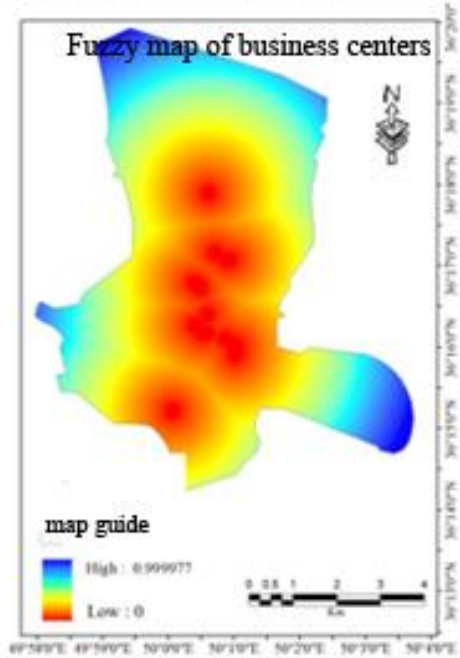
map guide
High : 1
Low : 0


Fuzzy map of business centers
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map guide
Low : 0

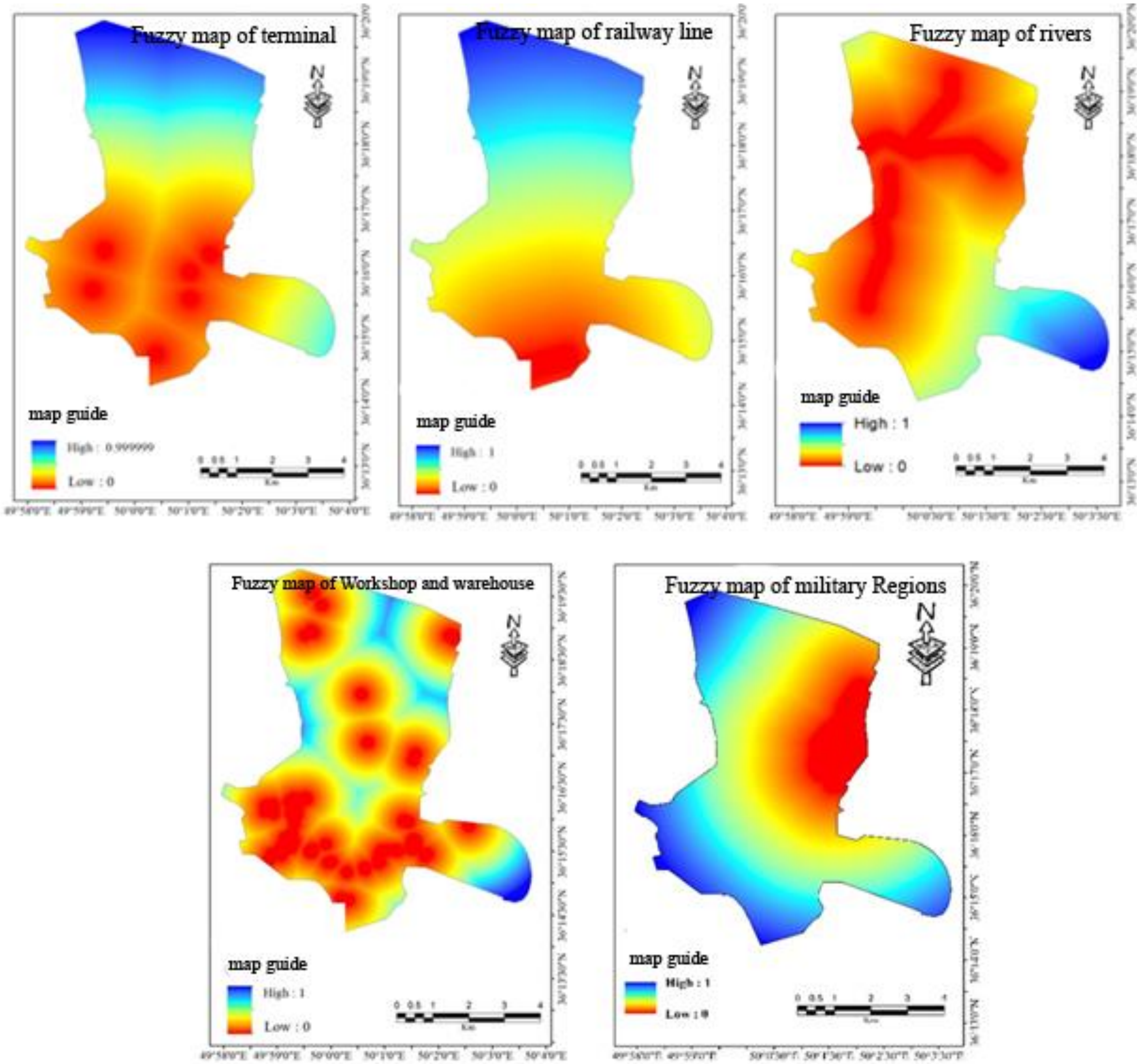

Fig. 4. Normalized maps

Weighting of the criteria

In this research, weighing has been performed using the fuzzy hierarchy process analysis method in MATLAB software. The final obtained weights of the criteria and sub-criteria are shown in Table 1.

Weighting of the maps

After obtaining weights, the weight of the layers was applied in the ArcGIS and the sub-criteria maps were produced and combined together and finally a map of four main criteria was obtained. Then the weight obtained by the FAHP process (Table 1) was involved in each of the main criteria maps and the weighted maps of the main criteria were obtained. (Fig.5)

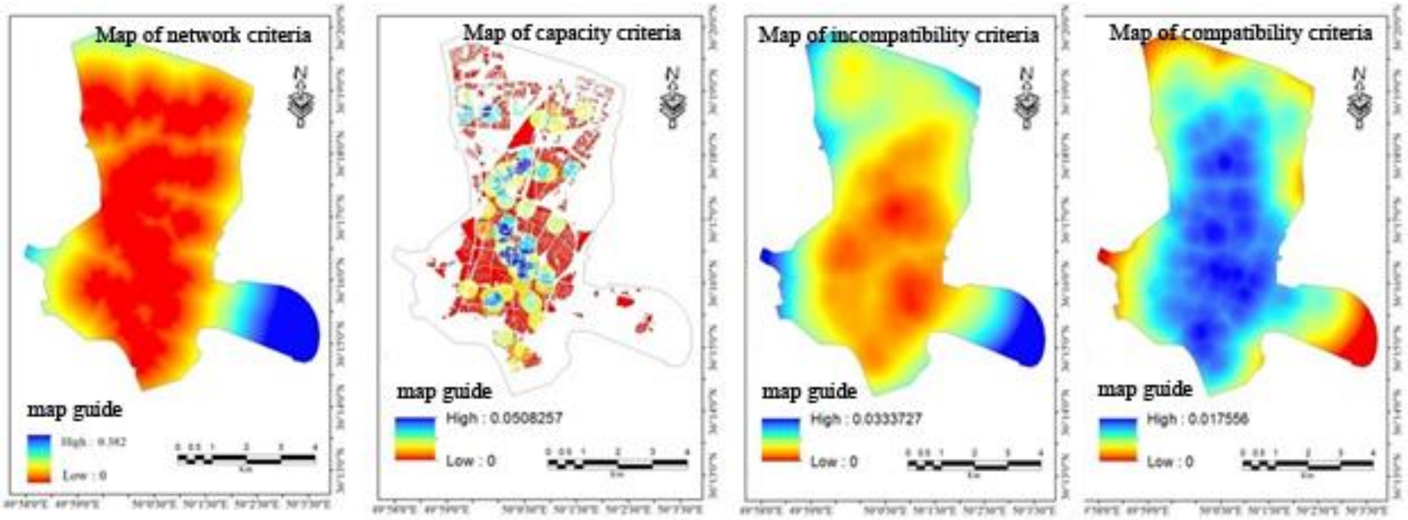

Fig. 5. Criterion maps, from right to left: compatibility, incompatibility, capacity and access radius (network)

Overlapping the layers

At this step, the weights obtained from FAHP (Table 1) were multiplied by main layers and the map of four main criteria was obtained, then the four layers were added together and finally classified. Five fuzzy operators contain "Fuzzy Subscription (AND) ", "Fuzzy Community (OR) ", "Fuzzy Algebraic Product", "Fuzzy Algebraic Sum" and "Fuzzy Operation Gamma" were used to combine the set of factors, and the final map was achieved (Figs 6, 7).

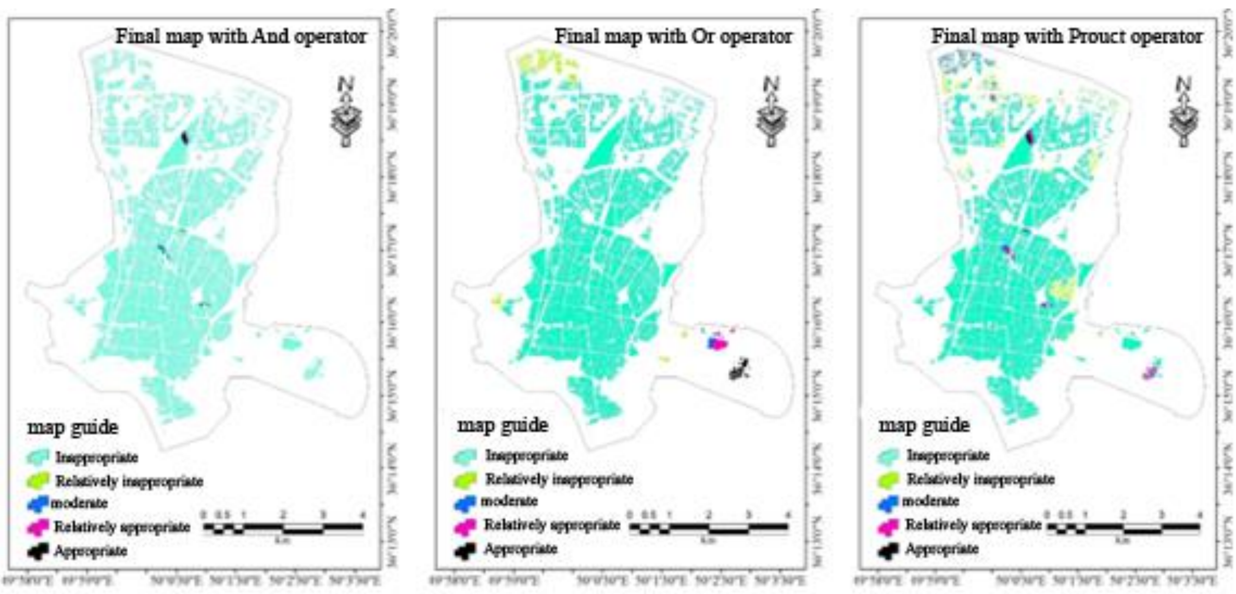

Fig. 6. The final map of the fuzzy operators, from right to left: Fuzzy Algebraic Product, fuzzy OR, fuzzy AND

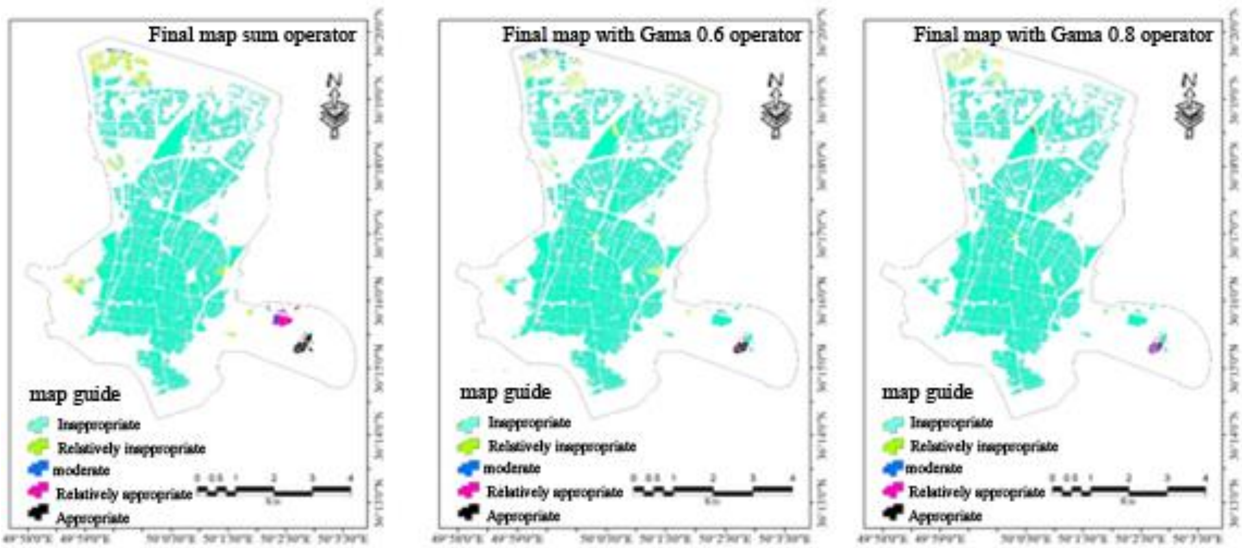

Fig. 7. Fuzzy Gama 0.8, fuzzy Gama 0.6 and fuzzy sum (from the right to the left)

Discussion

After rastering, the layers were normalized using the proper function and the value of all the maps were placed between zero and one that value of 1 means the high proportion of the desired layer for the construction of the school and the zero value has lowest proportionality (Fig. 4). After presenting the questionnaire and opinion of the relevant experts, the final weight of the criteria and sub-criteria used for this study was obtained and presented in Table 1. Based on the results, the criterion of access radius and compatibility were the most and the least important layers, respectively.

Table 1. Weight of criteria and sub-criteria

Criteria	**Capacity**		**Incompatibility**										**Compatibility**				**Access radius**
Sub-criteria	School density	Population density	Fire Stations	Railway line	Military Regions	Hospital	Fuel Station	River	Terminal and transport	Administrative - Disciplinary	Workshop and warehouse	Business centers	Sports	Cultural	Green space	Religious	
Final weight	0.176	0.112	0.034	0.029	0.028	0.025	0.023	0.02	0.016	0.012	0.007	0.004	0.067	0.044	0.019	0.003	**0.382**
	0.198		**0.288**										**0.192**				

The obtained weights were multiplied in the normalized maps and then the criteria map was obtained by overlapping the maps of each sub-criterion. The effect of this action is to determine the value of each layer in the final overlap so that all layers don't overlap with the same value. The final map of the four main criteria in this study is presented in Fig.5. Five fuzzy operators were used for the final overlap of the criteria. The subscription operator that considers the lowest value for each layer and is not risky, conversely, the community operator, considers the maximum amount of layers and is completely risk-averse. The subscription operator, the sum operator and the community operator are similar function; also the multiplication operator and the subscription operator functioned closely together. The gamma operator has a functional between the fuzzy multiplication and the fuzzy sum that the gamma index is between zero and one. As this number moves toward one, the closer to the sum and whatever goes to zero, it performs a multiplication. The output of the overlap is that the highest value of the map represents high fit with the target. In order to better understanding, fuzzy overlap output maps were categorized into 5 inappropriate, relatively inappropriate, moderate, relatively appropriate and appropriate classes.

Comparison of the results obtained in this research, which focuses on the locating of elementary schools in Qazvin using the FAHP method and the introduction of criteria and sub-criteria related to the construction of schools, shows that the maximum criterion weight is 0.382 for accessibility criterion and the minimum is 0.132 for the compatible usage. This result suggests that it is consistent with the average views of various experts in determining the appropriate location for building a new school. The results indicate that there are a shortage of schools in some parts of the city, therefore can be concluded that schools in Qazvin are not properly distributed in terms of optimal standards. Considering the 500 m operation radius and given that a large part of the region, despite the density of population, education, etc., isn't under the coverage of schools and the number of schools to cover the entire area is not sufficient and needs to be located and constructed new centers (Fig. 8).

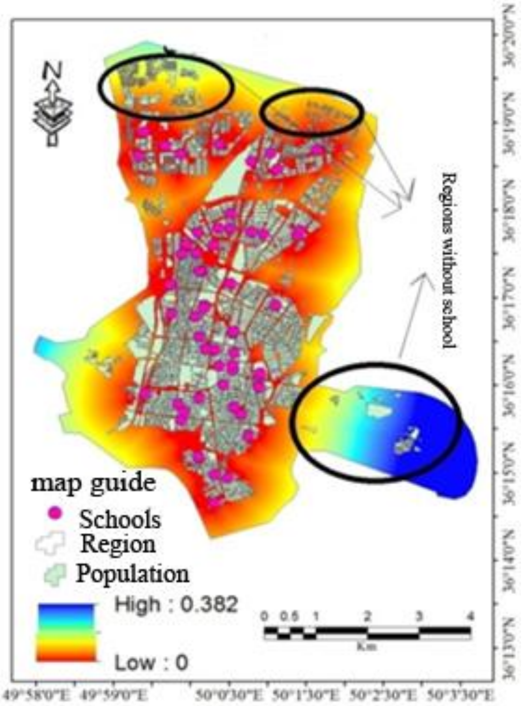

Fig. 8. Map of school distribution and access radius

The final maps of the Gama, Product, Sum, Or, And fuzzy operators were divided into five inappropriate, relatively inappropriate, moderate, relatively appropriate and appropriate classes and the following results were obtained.

Table 2. Area of different classes in different operators (ha)

Operator Class	Fuzzy OR	Fuzzy AND	Fuzzy Algebraic Product	Fuzzy Algebraic Sum	Fuzzy Operation Gamma	
					0.6	0.8
inappropriate	466.41	970.1	1195.22	847.26	1282.31	979.26
relatively inappropriate	840.40	330.06	98.51	398.08	40.05	300.62
moderate	14.68	22	25.84	63.25	11.05	41.05
relatively appropriate	3.01	8.4	11.08	14.85	3.8	8.09
appropriate	9.32	3.26	3.17	10.38	0.03	4.8

The results show that the gamma operator 0.6 considered a very small area (0.03 ha) as the appropriate area and the fuzzy sum allocated the most value (10.38 ha) for the appropriate class. Finally, according to the criteria used, experts' opinions, the method used in the research and also the field visits and area recognition, the fuzzy multiplication map was selected as the most suitable map for locating the school in Qazvin. Although the operator has been relatively strictly and has considered a small area (3.17 ha) as the appropriate area, it well detected areas deprived of the school (Fig. 9).

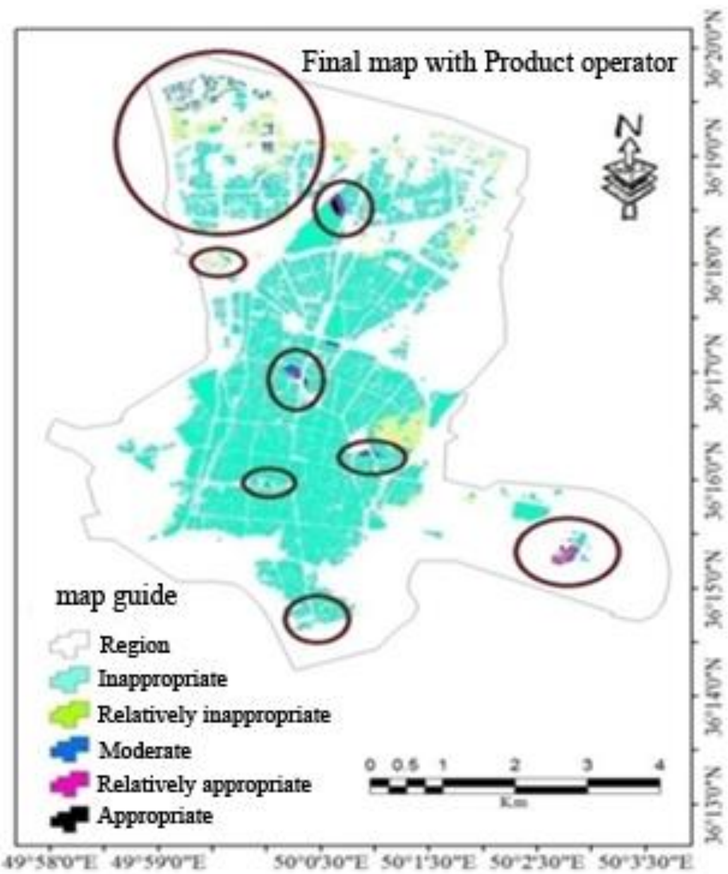

Fig. 9. Appropriate areas for the construction of elementary school in Qazvin

Recommendations

The ANP weighting can also be used to prioritize the importance of the criteria. It is also suggested that original and essential layers be used, and criteria that are highly correlated with each other be excluded from the research.

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