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The Development of Combined Cycle Power Plants Using Fuzzy AHP and OWA Techniques, Case Study Ghazvin Province

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ABSTRACT

Choosing a suitable location to construct power plants is necessary due to effects of the power plant location on the environment and the cost of production and transportation of energy. In this article, the most important criteria associated with selecting suitable locations to construct a combined cycle power plant and also the role and effectiveness of each of these criteria in site selection are determined. Arc GIS software is an efficient tool to integrate data in order to determine suitable locations for setting power plants. So, using fuzzy membership functions in Arc GIS, standardized maps based on their nature and roles are specified. The fuzzy AHP technique has been used to combine criteria based on their priorities and in the final step, Ordered Weighted Averaging method was handled to overlap and combine these layers. Risks associated with the location of power plants are determined at three levels including high, low, and, medium risk. The results show that some parts of east and southeast of Ghazvin province have a better condition to construct power plants, while the northwestern part is inappropriate.
KEYWORDS: GIS, Site Selection, Combined cycle power plant, Fuzzy AHP, OWA

INTRODUCTION

The demand of customers in this recent world is various and providing these requirements leads to pressure on natural resources [1]. Natural resources are key elements in the growth and development of each country, and along with human and financial resources can create basic socio-economic development. Exploitation of these resources should be reasonable and be based on achieving a sustainable development. Having appropriate levels of knowledge and awareness related to the use of technology and management of these resources is vital. Stockholm conference in 1972 was the commencement of worldwide concern about the environmental effects of industry on natural resources [2,3]. One of the effective tools for optimal land use planning is an evaluation of land use suitability which plays important role in minimizing environmental conflicts and disturbance [4]. Specifying natural and man-made borders (fault lines, rivers, power lines, roads, gas lines and so on) are a key point in determining the optimal uses of land in settling activities and population centers [5].

Electrical energy has an important role in human life and it is also an essential factor in economic prosperity, social welfare, and development of industry and agriculture. In Iran, the demand for electrical energy consumption is constantly increasing as a result of growing population, rising per capita consumption of electrical energy, the development of industrial and agricultural sectors and etc. So, to provide electrical energy some projects have been predicted and developed. Power plant networks as sources of electrical energy generation are the most important part of the energy transmission and distribution. Providing and developing these networks involves measurements to construct new plants and expand existing plants [6]. Planning to expand power plants with the aim of finding an appropriate site to develop plants is one of the most important steps. Construction of power plants helps governments to provide energy for consumers. So, in the process of energy development plans capacity, time and place of the new plants should be specified[7]. Introducing industrial development to any region brings some challenges between environment and industrialization. To provide proper management and reduce risks, these challenges should be identified and analyzed. Therefore, to develop infrastructures in any region, ecological resources should provide a sustainable and balanced backrest for the weight of the structures, and provide access roads to the area. This region should also be able to attract and decompose pollutants produced by industrial activities[8].

The results of the decision making in some cases are so important that wrong decisions can create irreparable harm. Therefore, selecting the best and proper techniques is very important for decisionmakers. Different methods of multi-criteria decision-making (MCDM) have been used in a variety of applications to prioritize and

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choose appropriate alternatives among different options. However, most of the data which is provided for decision makers is based on probabilities and has uncertainty due to ambiguity in the nature of the problems, inaccurate amounts and measures [9]. A proper MCDM model should be able to present interrelationships among different factors and specify the priority of each option through each criterion. There are different methods in MCDM models. Any of these methods has its potentials and limitations and cannot be used for decision-making in all multi-criteria problems. So, choosing proper method is an important factor in using this model [10]. To select a suitable method we should determine, whether these criteria have an effect on each other or not?, Are these criteria qualitative or quantitative?, Are they positive or negative?, Is there any accessibility to the relative weight of indices?, Is there any necessity to get information from decision makers during the process of problem solving?, and other cases like these questions which can be mentioned [11].

One of the MCDM methods is Analytic Hierarchy Process (AHP). It is based on a hierarchical framework which by using a set of pair-wise comparisons can analyze the importance of criteria, sub-criteria and other alternatives [12]. Since 1970, Saaty introduced this method[13]. Some of the judgments by AHP is uncertain and results are not reasonable, so fuzzy analytic hierarchy process was devised to overcome this problem[14]. Results of multi-criteria evaluation methods can be improved by using Ordered Weighted Averaging (OWA) method. OWA is one of the decision-making methods which has the abilities to consider priorities and subjective assessments of decision makers. OWA function proposed by Yager in 1988[15]. This method is capable of considering risk-taking and risk-averseness of decision maker in the process of decision-making and also it is able to adopt a final decision based on the risk-taking and risk-averseness. In the case of decision-making, risk-taking people concentrate on good properties of options while the risk-averse people emphasis on bad properties of options[16,17].

Many studies have been done with regard to criteria and factors influencing the choice of location to construct power plants [18,19,20,21,22]. Public Service Commission of Wisconsin (PSC) in the United States have determined and released main principles for locating a new thermal power plant. These principles, according to the conditions which they can be used in different technologies, had been divided into 6 categories including; site requirements, public health and safety, environmental impacts, land use effects, economic effects, and social effects [18]. In Iran, an environmental group named SABAa, have implemented several projects using GIS in order to locate thermal power plants. In these projects, required maps for each factor were provided and combined using the Boolean method [23,24]. The main weakness of these projects is the integration of maps without weighting of the factors. In many similar studies fuzzy logic and fuzzy functions have been used to determine the appropriateness of different locations on the maps and to combine maps, respectively [25, 26, 27].

The purpose of this paper is to investigate Ghazvin province lands to determine suitable locations to construct combined cycle power plant using Fuzzy AHP and OWA techniques. The province of Ghazvin is located in the center part of Iran. Agriculture and human settlements are mainly activities in this.

MATERIALS AND METHODS

Study area

Qazvin Province located in the center of Iran with an area of 15821 Km^2 and latitude from 48°45’ to 50° 50’north, and longitude from 35°37’ to 36°45’ east. Qazvin province is surrounded by central Alborz, Ramnd and KhrqanMountains from three directions and has developed extensive plains from north to south (94 km) and from east to west (74 km). Altitude in this region is variable from the highest point with 4175 m to lowest point with 300 m. There is a vast plain in center and east area of Qazvin province which its slope extends from northwest to southeast. This variable topography has created different climatic conditions.

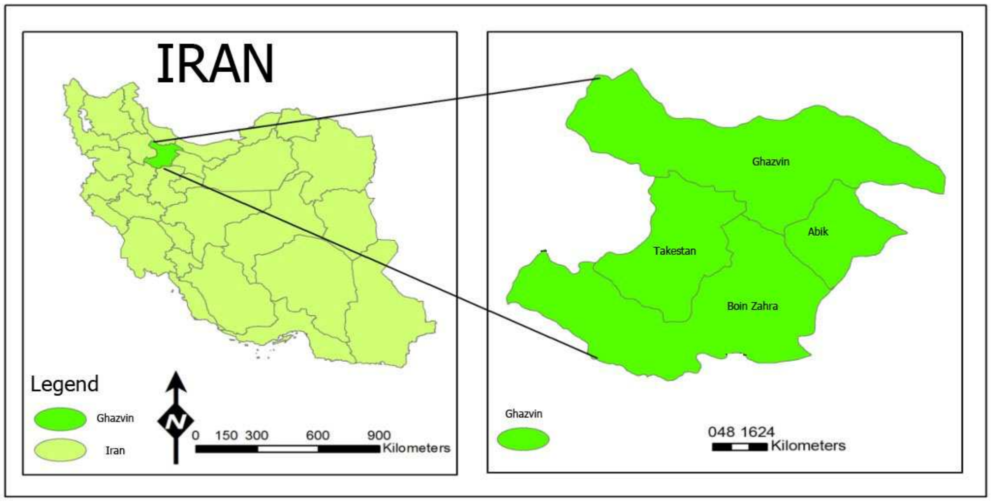


Figure 1. Geographical location of the study area

Determining a suitable location to construct a power plant quietly depends on a complete and accurate understanding of the effective factors which are important in site selection. In this study, determination of important technical, economic, social and environmental factors for site selection was based on interviews with experts and studying relevant texts. Then among these factors, those which had the possibility to data preparation and modeling were chosen. In fact, the provision and preparation data layers from some of these factors and then enter them into decision-making models are difficult or impossible. For this reason, in this study, factors have been selected based on the possibility of creating a map layer for them in Arc GIS. Table 1 shows important factors in the preliminary stage of site selection for combined cycle power plant and it also determines the importance and impacts of these factors. It should be noted that these factors and their importance in different situations is varied and they may be removed or added at different projects depending on their importance in the project. Selecting factors in this study are based on factors determined by the PSC, exports opinion and available data in Qazvin province [18,21,22,23,24].

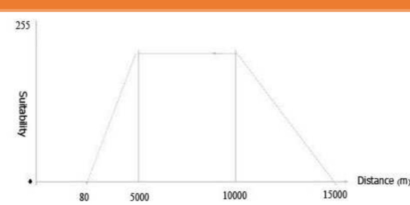
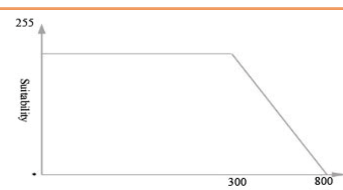
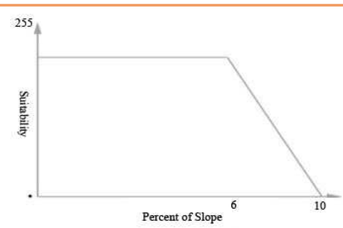
Selecting criteria and data preparation

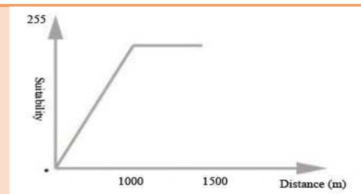
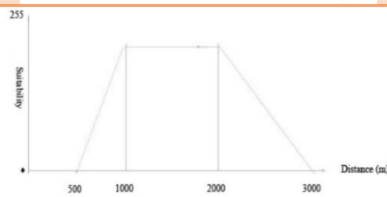
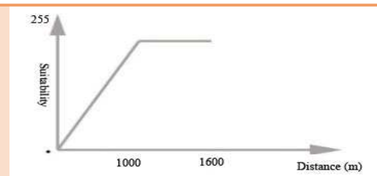
Relevant criteria were selected based on the condition of similar projects and opinion of various experts. Then, these criteria regarding the conditions of the study area, natural features, infrastructure constraints, and limitations of data were reviewed and screened. At the end, 8 criteria were considered in locating the power plant in Qazvin province. Of each criterion, a map layer in the Arc GIS software was developed as a standard map and all data layers in the 39th northern zone were projected based on UTM system and WGS1984. Figure 2 shows a land suitability assessment model for locating combined cycle power plant. Locating suitable places to establish plants in this study has been done using ordered weighted averaging. Weighting to each criterion was based on fuzzy AHP. To standardization, layers should be in the form of raster formats. Therefore, point and linear layers including; distance from urban and rural areas, fault, waterways, and main roads were coded using a Distance module in Arc GIS. Polygon layers including; geology, land use were encoded by expert opinion according to their suitability. By giving codes upper than 1 to layers and using Feature to Raster module, layers are converted from feature to raster. With the standardization of data layers, all values were converted to the same domain between 0 and 255. And in the IDRISI software, Fuzzy modules were used for standardization of factors using membership functions. This module has four functions: sigmoid function, J-shaped, linear and User-defined function in three ways: Increasing, decreasing and symmetric. In this study, for each criterion, fuzzy linear membership function was defined and fuzzy maps for them were prepared in IDRISI. Table 2 shows criteria which were standardized by the fuzzy membership function.

Table 1. Criteria and sub-criteria for Site Selection of Combined Cycle Power Plant

Criteria	Sub-criteria	Importance in site selection	Impacts
Access roads	Freeway Highway	Access to the site and carry equipment	Economic, Social, Traffic safety
Features related to water	Lake	Water supply and wastewater disposal	Economic, Social, Environmental
	River	Water supply for security of power plant structures	
Natural limitations	River Seismicity of the region Swamp Wetland Sandy soil	Providing security for power plant structures	Economic
Geology and soil	Soil type	Providing security for power plant structures, Disposal of solid waste	Economic, Environmental
Topography	Elevation	Increase efficiency of construction of power plant structures	Economic
	Slope	Facilitate the construction of power plant structures and access roads	Economic, Environmental
Environmental limitations for special structures	Land use (orchard, forest, farm)	Reducing environmental damage caused by the construction and operation of power plants, Providing security	Economic, Environmental (air pollution, Protection of rare flora and fauna species)
Population centers	City	Supply human resources	Economic, Environmental
	Village	Supply human resources	
	Residential areas	Reducing adverse effects on the environment	

Table 2. Standard criteria according to membership functions

Criterion	Function	Type of the function	Diagram of the function	Control point			
				A	B	C	D
Distance from access roads network	Linear	Symmetric		15000	10000	5000	80
Altitude	Linear	Decreasing		800	300	300	300
Slope	Linear	Decreasing		10	6	6	6

Distance from seismicity regions	Linear	Increasing		1500	1500	1500	1000
Distance from surface water	Linear	Symmetric		3000	2000	1000	500
Distance from fault lines	Linear	Increasing		1600	1600	1600	1000

Weighing criteria using FAHP method

In the process of multi-criteria evaluation, weighting makes different layers have different values, and so analyses are more accurate. Thus, if criteria were not weighted all layers have the same value and the result can be very misleading. In this paper, Fuzzy AHP has been used for weighting criteria.

Fuzzy Analytical Hierarchy Process

The concept of fuzzy in the AHP method has been considered indirectly and without the use of fuzzy sets. In fact, in this method through linguistic expressions, the concept of fuzzy is used to determine the comparison matrix [28]. Buckley method is one of the most practical and suitable techniques among the methods that have applied the concept of the fuzzy hierarchical analysis model. Fuzzy AHP method which was provided by Buckley is a generalized from of AHP classic that can apply fuzzy numbers and geometric averaging technique to pair comparison of options and to obtain weights and preferences, respectively. This method can easily generalize to a fuzzy method and determine answers to units for pair-wise comparison matrix. Decision-makers can determine paired comparisons of elements in each level in the form of trapezoidal fuzzy numbers [29]. Buckley's algorithm can be expressed in the following four steps;

Step 1. In this step, decision maker determines pairwise comparison matrices. Elements of these matrices are trapezoidal fuzzy numbers. If preference of i on j showed by $\tilde{a}_{ij}=(a_{ij}, b_{ij}, c_{ij}, d_{ij})$, so preference of j on i is,

$$\tilde{a}_{ji}=\left(\frac{1}{d_{ij}},\frac{1}{c_{ij}},\frac{1}{b_{ij}},\frac{1}{a_{ij}}\right) \qquad (1)$$

If i=j, so $\tilde{a}_{ij}=\tilde{a}_{ji}=(1,1,1,1)$

Step 2. In this step, fuzzy weights $(\widetilde{W}_i)$ will be calculated. For this purpose, geometric mean of each row of the matrix pair-wise comparison can be determined using the following equation,

$$\tilde{Z}_i=(\tilde{a}_{i1}\,.\,\tilde{a}_{i1}\,\ldots\,.\,\tilde{a}_{in})^{1/n} \qquad (2)$$

Then $\widetilde{W}_i$ can be obtained from the following equation,

$$\widetilde{W}_i=\tilde{Z}_i\,.\,(\tilde{Z}_1\oplus\tilde{Z}_2\oplus\ldots\oplus\tilde{Z}_n)^{-1} \qquad (3)$$

Multiplying and adding operators in this equation are fuzzy operators. $\widetilde{W}_{\mathrm{i}}$ is calculated as follow; the left and right bound of aij fuzzy set are defined respectively as the following relationships,

$$f_i(\mathrm{a}) = \left[\prod_{j=1}^{n}\left((b_{ij}-a_{ij})a+a_{ij}\right)\right]^{\frac{1}{n}} \quad , \quad \mathrm{a}\in[.,1] \qquad (4)$$

$$g_i(\mathrm{a}) = \left[\prod_{j=1}^{n}\left((c_{ij}-d_{ij})a+b_{ij}\right)\right]^{1/n} \quad , \quad \mathrm{a}\in[.,1] \qquad (5)$$

Also $a_i=\left[\prod_{j=1}^{n}a_{ij}\right]^{1/n}$ and a = $\sum_{i=1}^{m}a_i$ can be defined as b_i, b, c_i c, and d, d_i. Thus, $\widetilde{W}_{\mathrm{i}}$ is obtained from the following equation.

$$\widetilde{W}_i=\left(\frac{a_i}{d},\frac{b_i}{c},\frac{c_i}{b},\frac{d_i}{a}\right) \qquad (6)$$

So that the membership function $\mu_{\widetilde{W}_i}(\mathrm{x})$ is defined as follow:

$$\mu_{\widetilde{W}_i}(x) = \begin{cases} 0 & \text{if} \quad x \le \left(\frac{a_i}{d}\right) \text{or} x \ge \left(\frac{d_i}{a}\right) \\ 1 & \text{if} \left({b_i}/{c}\right) \le x \le \left(\frac{c_i}{b}\right) \\ a \in [.,1] & \text{if} \left(\frac{a_i}{d}\right) \le x \le \left(\frac{d_i}{c}\right) \\ a \in [.,1] & \text{if} \left(\frac{c_i}{b}\right) \le x \le \left(\frac{d_i}{a}\right) \end{cases} \quad (7)$$

If (a_i / d) ≤ x ≤ (b_i / c), X can be calculated from the following equation,

x = f_i(a)/g (a) (8)

If (c_i / b) ≤ x ≤ (d_i /a), x can be calculated from the following equation,

x = g_i(a) / f(a) (9)

so,

f(a) = $\sum_{i=1}^{m} f_i$(a)

g(a) = $\sum_{i=1}^{m} g_i$(a)

Similarly, the second step is repeated for all values of i and j and fuzzy priority r_{ij} is calculated.

Step 3. In this step, with combination of preferences and obtained weights in the previous step, fuzzy utility values $\widetilde{U}_i$ is calculated using the following equation,

$\widetilde{U}_i = \sum_{j=1}^{n} \widetilde{W}_j \, \tilde{r}_{ij}$ (10)

Step 4. Defuzzification of fuzzy weights: In this study, centroid fuzzy method has been used for defuzzification. This method is the most common method for convert fuzzy to the classical quantity which by the following equation Z * can be calculated.

$$Z^* = \frac{\int \mu_{\tilde{C}}(z).z \, dz}{\int \mu_{\tilde{C}}(z) \, dz} \quad (11)$$

Fuzzy logic

Fuzzy logic was presented by Lotfi Zadeh in 1965. According to his view, human logic can benefit from the concepts and knowledge that its boundaries are not well defined. Fuzzy logic includes a range of theories and methods, which essentially is built based on two concepts: Fuzzy sets and linguistic variables [30]. A fuzzy set is a collection whose elements with a membership degree (μ) belong to that set. This membership function for each number like X is a triangle and defined by the following equation,

$$u_{\tilde{A}}(x) = \begin{cases} (x-1)/(m-1), l \le x \le m, \ l \ne m \\ (x-r)/(m-r), m \le x \le r, m \ne r \\ 0 \text{ , Otherelse} \end{cases} \quad (12)$$

Figure 2. Shows triangular fuzzy numbers.

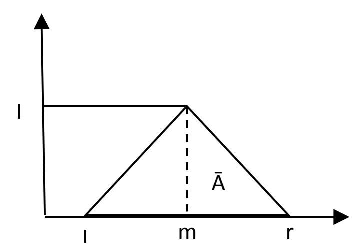


Figure 2- Triangular fuzzy numbers

Ordered Weighted Averaging Method

In the matter of decision-making, risk-taking people concentrate on good properties of an option while risk-averse people insist on bad properties of an option and then they can select options based on it [16, 17]. The ordered weighted averaging can be used for calculating the amount of the risk-taking and risk-averse and evolves it in selecting the final option. F is an OWA function with n dimension. This is a $F: R^n \to R$, with weight vector $w = (w_1, \dots, w_n)^T$ for a collection of data input X=($x_1, \dots, x_n$) which is supposed to be aggregated with each other so that:

$F(x_{1,\dots,x_n}) = \sum_{i=1}^{n} w_i \, b_i = W^T$B (13)

Where w_i can be true in the following situation,

ϵ [0, 1] i =1,…, n W_i

$\sum_{i=1}^{n} w_i$=1 (14)

Where bi and largest i value is sorted from ascending to descending. The navigation concept is defined as follow:
Orness (w) = $\alpha=\frac{1}{n-1} \quad \sum_{i=1}^{n}(n-i)$ w $\quad 0\leqslant\alpha\leqslant1$ (15)
Where it is in the interval (0, 1) and indicates the degree of emphasis of the decision maker on risk-taking and risk-averse. Orness degree or risk-taking shows OWA operator's position among AND (minimum) and OR (maximum) relations [31]. The higher degree of navigation (be closer to 1), the optimism and risk-taking of decision maker will be greater, and the amount lower navigation (closer to zero), the cynicism or risk-averse of decision maker will be greater. Generally, an OWA operator with Orness (w)> 0/5 represents a risk-taking decision maker or optimism, Orness (w) = 0/5 represents a neutral decision maker, and Orness (w) <0/5 represents a risk-averse decision maker or pessimistic. The most important aspect of using of OWA operator is, determining the weights. In this paper, minimum/maximum distance method has been used to determine weights. This model has been introduced by Wang and Park [11].

Minimum δ

Orness (W) $=\sum_{i=1}^{n}\frac{n-i}{n-1} w_i = \alpha \quad 0\leq \alpha \leq 1$ (16)

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

w_i-w_{i+1}- $\delta \leq 0$ i=1,…,n-1

w_i-w_{i+1}+ $\delta\geq 0$ i=1,…,n-1

$w_i \geq 0$ i=1,…,n

This method is a linear model, and determines weights according to the amount of given navigation. In this model, the distance between adjacent weights under navigation has been reduced as much as possible. The obtained weights of this model have been scattered regularly and follow an arithmetic progression.

Preparing Restriction Maps

Restrictions divide options into two categories including; favorable options (1) and unfavorable options (0). In fact, impose restrictions on multi-criteria evaluation separates options that there is no possibility in them to construct power plant from the other options and removes them from the decision-making process. There are many limiting factors in locating power plant site. In this study, opinions of different experts were used and according to the condition of the region, the distance of buffers was determined. Limiting factors in power plant location have been shown in Table 3. Based on the results of fuzzy AHP method, weights of the criteria for site selection of combined cycle power plant in Qazvin province have been determined and showed in Table (4). As can be seen from the table distance from population centers has the highest weight, and slope has the least weight among chosen criteria.

Table 3- Limiting factors in locating the power plant

Limiting factors	Criteria for mapping restrictions
Rivers	500 meters buffer
Access roads	80 meters buffer
Inappropriate slope	Slope> %10
Fault lines	1 kilometer buffer
Urban residential centers	3 kilometers buffer
Rural residential centers	1 kilometers buffer
protected areas	2 kilometers buffer

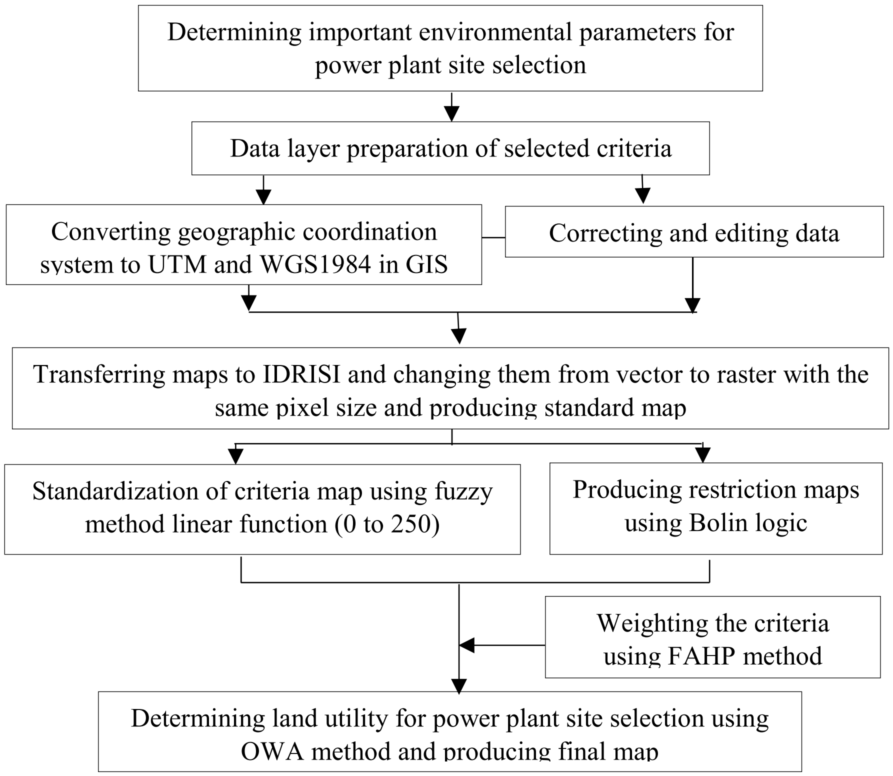


Figure 3- Land suitability assessment process model in order to locate a combined cycle power plant in Ghazvin province

RESULTS

In this article, relevant criteria were selected based on similar experiences and opinion of experts. The criteria were screened and reviewed based on the conditions of the study area, natural features, infrastructures and data limitations. In Table 4, all standardized criteria using fuzzy membership function have been shown. Based on the results of FAHP method, the weights of the criteria for site selection of combined cycle power plant in Qazvin province were determined and illustrated.

Table 4- The weights of selected criteria for locating the power plant

Criterion	Weight of each criterion
Distance from access road	%13
Distance from surface water	%15
Geology and soil	%10
Slope	%08
Elevation from sea level	%12
Land use	%11
Distance from fault lines	%14
Distance from residential area	%17

At the end, these weights were multiplied with standard layers of the criteria. Then, using OWA al layers were combined, and findings were presented at three levels of risk, including low-risk (AND), high-risk (OR) and the intermediate-risk (WLC). Figure 5 shows these results.

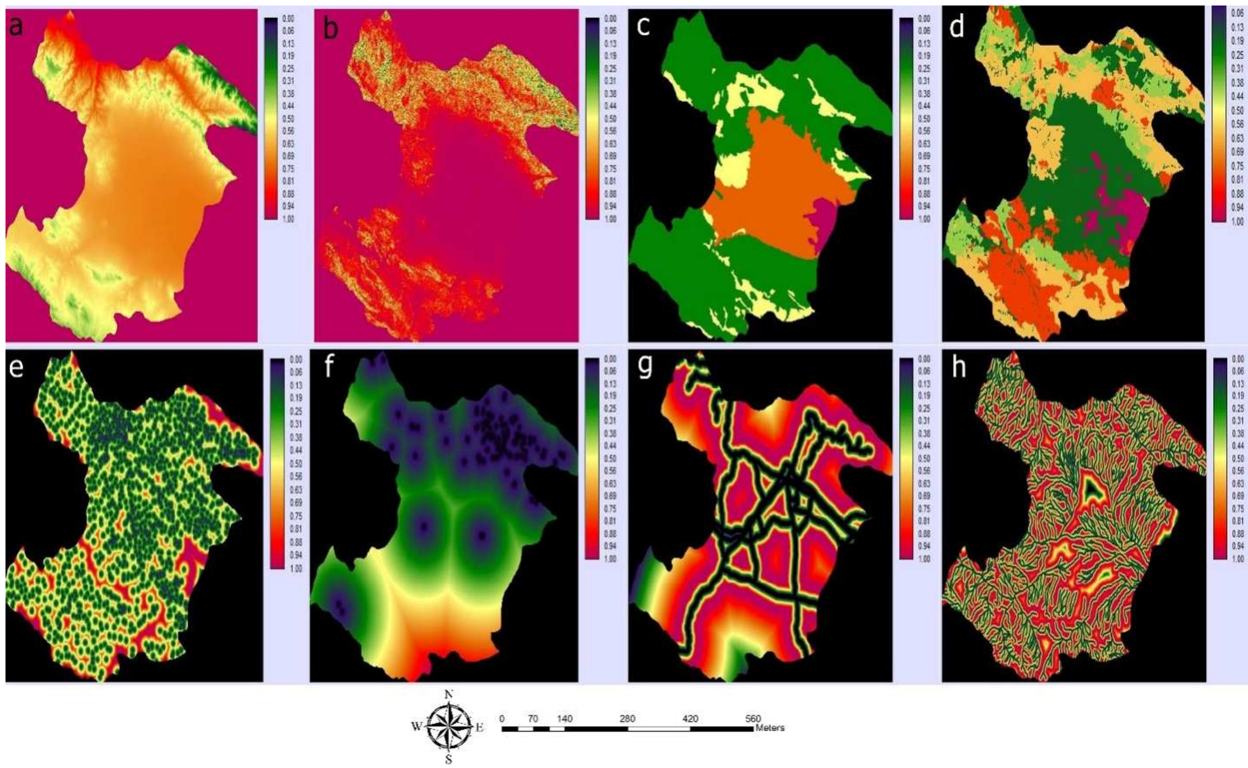


Figure 4- Fuzzy layers; a) Elevation, b) Slope, c) Geology and soil, d) Land use, e) Distance from population centers, f) Distance from seismic points, g) Distance from access roads network, h) surface water resources.

In order to create an FAHP-OWA model in the process of determining a suitable location for the construction of combined cycle power plant, criteria are combined and finally weighted[31]. Restriction maps are used for strict decision making in the process of determining suitable areas for urban development. In this research, maps of rivers, access roads, improper slope, fault lines, urban residential, rural residential centers and protected areas were considered as restriction maps. Then, these maps were standardized by fuzzy logic. In the standardization method, maps for each factor are reclassified using fuzzy operators in a range between 0 and 1. So that pixels that their numerical value is zero or close to zero are less suitable for the establishment of the power plant and pixels that their numerical value is 1 or close to 1, are more suitable for the establishment of the power plant. After standardization of criteria, they were weighted by FAHP method. Then, the second set of weighting as the ordered weights were applied. This type of weighting provides the possibility of control to the overall level of substitution relationship between factors (Trade off) and to the level of risk in the proportionality determination. Sequence weighting pixel by pixel has been used for criteria ranking. So that they are determined by the order of their rank in each position (pixel) in all factors. There are sequential weights (8 ordered weight) for weighting the criteria. The first ordered weight is allocated to the factors with the lowest rank in each pixel and the second ordered weight is allocated to the second lowest rank, and the eighth ordered weight is related to a factor with the highest rank in each pixel. The total of ordered weights should be 1. So, it is possible that an ordered weight allocates to different factors depending on their relative rank [32]. As can be seen from the output maps from the modeling, areas in the southeast and east of Qazvin Province is suitable for the establishment of the power plant. According to AND, OR and WLC options, the most suitable places for the construction of combined cycle power plant are southeast, center and east areas of Qazvin province.

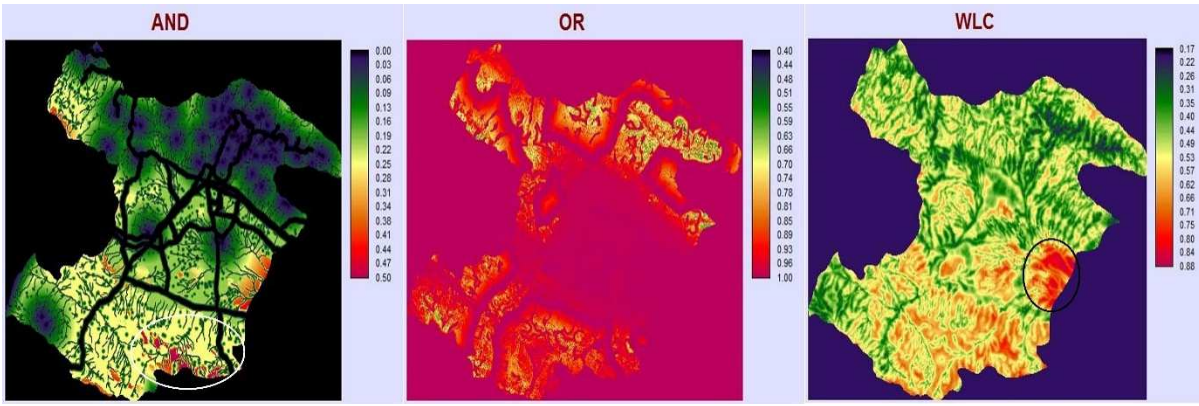


Figure 5- The resulting map of locating by OWA method: Low risk (AND), High risk (OR) and Moderate (WLC)

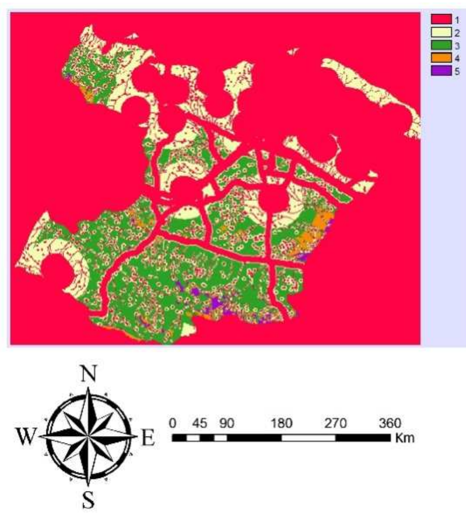


Figure 6- The classified map of AND operator

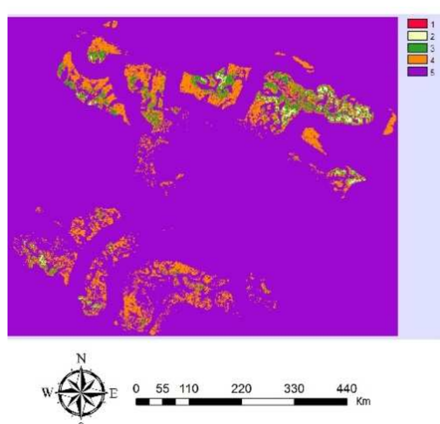


Figure 7- The classified map of OR operator

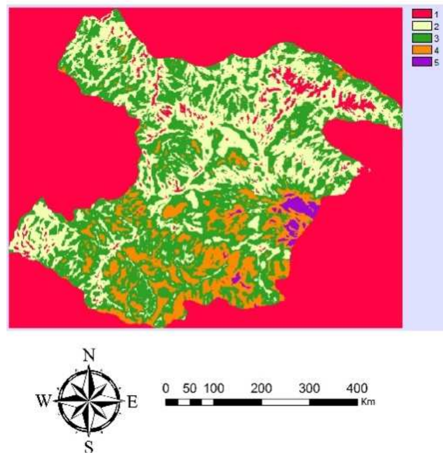


Figure 8- The classified map of WLC operator

Table 5-The areas of classified areas obtained in OWA method

Categories	Suitability of the area for construction of the power plants	Area (km^2)		
		AND	OR	WLC
1	Very weak	22266/17	3/39	15276/10
2	Weak	3858/53	138/21	5688/85
3	Medium	3667/64	549/02	7029/96
4	Good	309/95	2200/28	2047/86
5	Very good	162/2	27373/56	221/72

Conclusions

OWA operator can use a decision matrix to produce different answers based on mental qualities of decision-makers. According to the results of low-risk (AND), high-risk (OR) and medium-risk (WLC) maps, east and southeast area of Qazvin are the most suitable place to build a combined cycle power plant. Low-risk map (AND) is stricter than others in choosing a suitable location to construct power plants and it shows the southeast area of this province. Medium-risk map (WLC) shows that east area of the region has the medium risk and is relatively suitable to construct a power plant, and high-risk (OR) map which illustrates parts of northwestern, northeastern, southwestern and south are inappropriate to construct such plants. Totally, the northeast part of the study area has the most level of risk and construction of power plant is not recommended there. Most of the previous researches have been conducted to develop systematic hydroelectric power plants using methods like TOPSIS. In TOPSIS method only one option is selected and it is not able to model and consider the mental qualities of decision makers and answer the question of all decision-makers (risk-taking / risk-averse). This method also is risk-averse and must be considered in the decision-making process to determine the level of the risk. Therefore, in this study, in addition to the use of FAHP method that applies a vast range of values to the expression of uncertainty of decision makers, OWA method is used to model mental qualities of decision makers and to choose the best option based on risk-taking and risk-averse of decision-maker. Relationship feedback is also another advantage of this method compared to other methods of decision-making. So, each element in this method can have impacts on the other elements in all level and in contrast gets influence from each of them. By using OWA, final decisions and answers are carefully chosen and decision-making is closer to the reality condition. Another important point about OWA operator is the definition of optimism that can indicate to what extent the behavior of OWA operator is similar to the OR operator. If the combined amount is close to the maximum of arranged inferences, it shows that combine process behaves like OR operator, and if the combined amount be close to the minimum of arranged inferences, it indicates that combine process behaves like AND operator.

Proposals:

OWA method is capable of considering mental qualities of decision makers in the estimation of the cumulative amount, while many other operators do not have this important feature. So this method can be a good way for other researchers to site selection.

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