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ORIGINAL ARTICLE

Evaluation of Industrial Development Potential Using a Sustainable Approach Based on VIKOR and ANP Hybrid Methods in a Fuzzy Environment: a Case Study in Azarshahr City, Iran

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ABSTRACT

The strategic advantages of sparsely populated towns near major cities make them suitable for the industrial activities. This study was aimed to identify and rank the industrial estate development environmental factors in order to minimize negative environmental effects. In this study, the criteria for industrial development were first determined; then, the weight of each criterion was obtained through the technique known as Analytical Network Process (ANP). These indices were entered into Geographic Information Systems based on 13 defined layers, then compiled and standardized using the fuzzy method. Afterward, selected options were ranked via the VIKOR technique and the final site for industrial development was determined in a fuzzy GIS. According to the results, the most important industrial estate development suitability criteria assessments were environmental, social, and economic, respectively. The results also showed that the sub-criterion of distance from city was the most important environmental pollution factor. The environmental pollution was considered a sub-criterion of social criteria in this study. Generally, environmental criteria to develop an industrial estate were significantly important and should be duly considered in the development of industrial towns. Additionally, the main cause of environmental problems in industrial towns was their proximity to a city zone. This methodology may provide useful information in the development of industrial settlements and may also reduce environmental pollution.

Keywords: *Industrial Development Potential; Environmental; VIKOR; Fuzzy Geographic Information Systems; Analytical Network Process*

INTRODUCTION

Since the beginning of the 20th century, industrial development has led to the emergence of industrial complexes, zones, poles, or towns and has gained crucial importance in a country's progress and exploitation of resources. Moving toward industrialization, countries need to select and organize specific locations for the establishment of industrial units to minimize adverse environmental impacts [1]. This process is influenced by factors such as population growth, employment, land constraints, and environmental protection, as well as developmental and industrial land use planning. Having considered these issues, irregular industrial areas development can be prevented and their destructive environmental

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pollution effects can be managed, in particular [2-3-4]. Therefore, site location is a key step to establish industrial units. The outcomes of this decision appear in long-term and have significant economic, environmental, and social effects. Although, industrial zones positively affect their surrounding regions. But, in a broader perspective, large industrial units can alter economic, social, cultural, and environmental conditions. An economic site has an important impact on the required amount of initial investment, and the cost of product and service in the operating time [5].

Legislation in Iran encourages entrepreneurs and investors to focus on towns located within 30 km radius of large cities. A set of decision-making indices and criteria should be defined to select an appropriate location and their degree of importance should be determined through decision models [6].

In different studies, industrial development potential factors were evaluated by many researchers. Distance from cities, roads and railways accessibility, topography features, faults and earthquakes geology were the most important indices of the HSE management system [7]. Liu et al. reported that risks associated with industrial development potential, air pollution, and greenhouse gases were the most important industrial development potential indices [8]. Parajuli and Lee found that a big challenge for industrial development was policy and legislation amendments enforcement and the required safe environment and health standards accomplishment [9].

Multi-criteria evaluation techniques such as Analytic Network Process (ANP), Analytical Hierarchy Process (AHP), and GIS generally applied to determine and analyze the required for industrial site location and spatial analysis [10]. For example, Shahabi et al. investigated the potential and challenges of industrial towns located at Isfahan province through a brief investigation. This study showed a positive relationship between the density of industrial towns and the development level of the city [11].

Madadi in 2003 investigated the location of Shahrekord industrial town from an environmental viewpoint. The results of this study suggested that the presence of towns within a 3 km radius of Shahrekord can disseminate pollution in residential areas in several ways. Madadi also evaluted the development potential of industrial towns in the vicinity of this city [12].

Ahadnezhad et al. recommended AHP and VIKOR as suitable and systematic methods for removing biases from evaluations [13]. In a study conducted with the objective of locating industrial estates, Fernandez et al. introduced a number of social, economic, environmental, infrastructure, and planning criteria; and then, entered these criteria to AHP and GIS models to determine the best industrial towns' location in the northern regions of Spain. In this study, they evaluated the decision-making process based on the most important AHP determined criteria. After economic, social, planning, and environmental factors evaluation, this study reported that unemployment rate, industrial activities in the region, environmental management, environmental improvement programs, urban planning management, transportation, water and wastewater management were the most effective factors in industrial site location [3-14]. In this research, only the industrial towns' development effective parameters were ranked and did not considered as information layers [2].

A review on the available sources indicated a generalized application of the mentioned criteria and often limited to developing countries while the effective criteria have been ignored. The current study was aimed to evaluate industrial development potential in order to minimize adverse environmental effect. This research was conducted as a case study in Azarshahr, which is the second largest city of the East Azerbaijan province in Iran in terms of industrial development. The main question of this research was; what are the parameters of industrial development potential.

RESEARCH METHODOLOGY

A descriptive-analytic research conducted through library studies, field visits, and spatial and statistical analyses. In the present study, 13 criteria were determined using a hybrid VIKOR ANP, and GIS methods. This study was implemented at Azarshahr city located in East Azerbaijan province, Iran. This city has an area of over 840 km^2 with an average altitude of 1340 m. It is located at a longitude of 25 degrees and 46 minutes, and latitude of 2 degrees and 38 minutes. According to a 2011 census, this city has a population of 107,579 people. The administrative division has been presented in Figure 1.

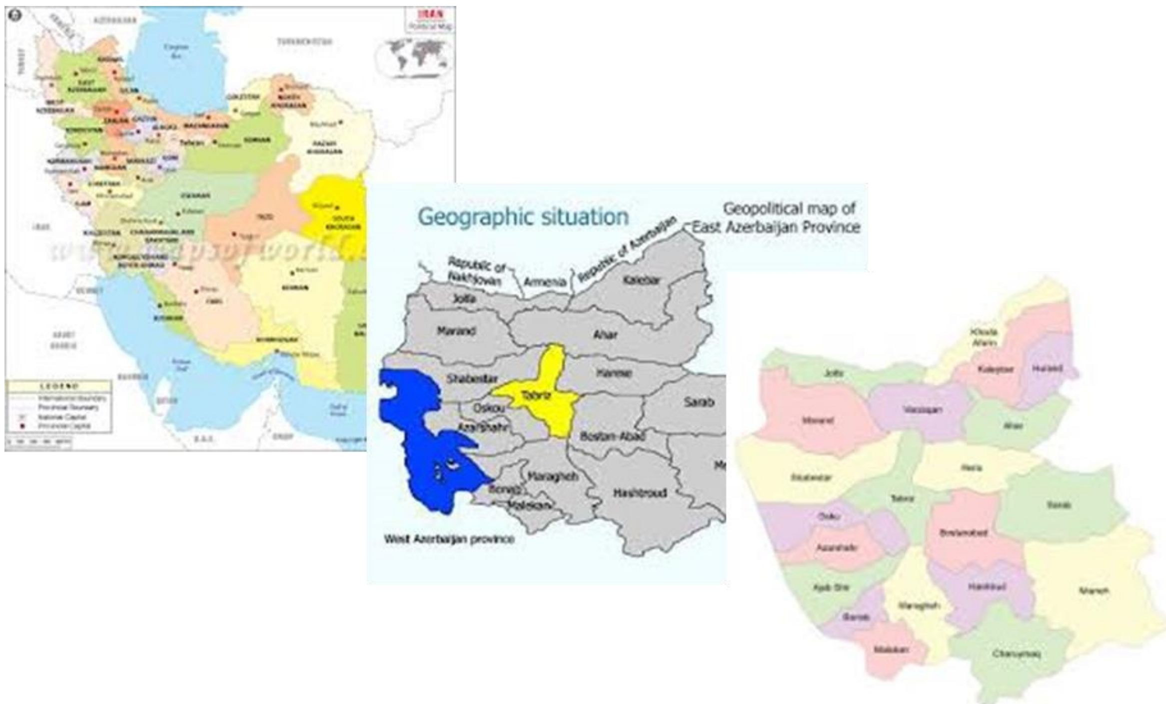

Fig. 1. Administrative division in the study area (country-province-city)

Based on the information obtained from questionnaires and experts' opinions, a number of industrial development potential indices were identified to analyze accurately. The industrial development potential criteria were defined by experts and available resources [5-7-8-9-15-16-17].

The study data included criteria maps listed in Table 1. Study tools (applications) included Autodesk Map 2012 (for the digitization process and editing the maps); Super Decision (for weighing criteria with the ANP method and conducting multi-criteria evaluation); ArcGis10.3 (for creating and completing base layer data, geo-referencing the maps, determining the system of coordination and image, using Spatial Analysis functions to integrate the maps); and VIKOR technique (to rank the options).

The necessary data layers and their resources have been illustrated in Table 1. The process of locating industrial development consisted following four main steps:

DETERMINING CRITERIA AFFECTING THE LOCATION:

Many parameters affect the process of locating industrial development, which usually depend on the region situation. In this study, after reviewing similar studies, consulting with experts, checking regulations of environmental protection organizations, and considering the general condition of the region and principles of sustainable development, 13 main parameters including three clusters of economic, social, and environmental parameters were identified as the main criteria affecting the location of industrial development. Consequently, these prepared information layers were evaluated using GIS [18-19].

WEIGHING THE CRITERIA WITH ANP TECHNIQUES:

The ANP is a more general form of the analytic hierarchy process (AHP) used in multi-criteria decision analysis. If criteria are dependent on

Table 1. Required data layers and resources to locate industrial development

Row	Parameter	Source
1	Distance from cities	1: 50,000 Map, Geographical Organization of Army
2	Distance from villages	1: 50,000 Map, Geographical Organization of Army
3	Roads and railways	1: 50,000 Map, Geographical Organization of Army
4	Land use	Ministry of Agriculture (Agricultural Research Institute)
5	Distance from power lines	1: 50,000 Map, Geographical Organization of Army
6	Land Topography (height)	1: 50,000 Digital Map, Geographical Organization of Army- DEM map
7	Slip-Slope	1: 50,000 Digital Map, Geographical Organization of Army- DEM map
8	Soil type	1: 100000 Map, Research Institute of Agriculture
9	Region Geology (karst and vulnerable areas)	1: 100,000 Map, Geology organization
10	Areas susceptible to earthquakes and faults	1: 100,000 Map, Geology organization
11	Vegetation	1: 100,000 Map, Research Institute of Agriculture
12	Surface water (river - spring - pond - dam)	1: 50,000 Digital Maps of Regional Water Organization of East Azerbaijan
13	Environmental protection areas	Digital Layer of Environmental Protection Organization

feedback then the ANP method should be used to obtain the criteria weight which was presented by Saaty [21]. The criteria in this study were weighted using the ANP method. The current study implementation stages were described as following model. These steps were consisted the following sub-steps:

a) Designing a location model based on the sustainable development indices and conversion of the problem to a network structure

After specifying the criteria, a coefficient for each criterion were determined. Therefore, an ANP structure of the proposed model was designed comprised three clusters (economic, social, and environmental), and 13 elements. The ANP model, the internal and external relationships of its elements based on experts' opinions have been shown in Figure 2.

Pairwise comparison of elements on each level was carried out according to their relative importance to the control criterion using the questionnaire (in the range of 1–9) in four rounds. Then, the geometric mean of the questionnaire was calculated and entered into Super Decision software through its Matrix menu [20].

b) Forming a pairwise comparison matrix and determining the priority vectors

Pairwise matrices were formed using expert judgments and comparisons based on independent criteria (control criteria). The team of experts composed of 10 professors with land-use planning and development evaluation specialization. The Cochran formula was used to determine the experts' panel list. Finally, with a 95% confidence, the number of experts was 9.85 out of 10. Based on the pairwise comparison of three clusters results, environmental and social clusters values were calculated 0.374 and 0.352, respectively which showed the greatest weight among the clusters. The inconsistency rate obtained for these comparisons was 0.023 (less than 0.1), indicating that they were acceptable [21].

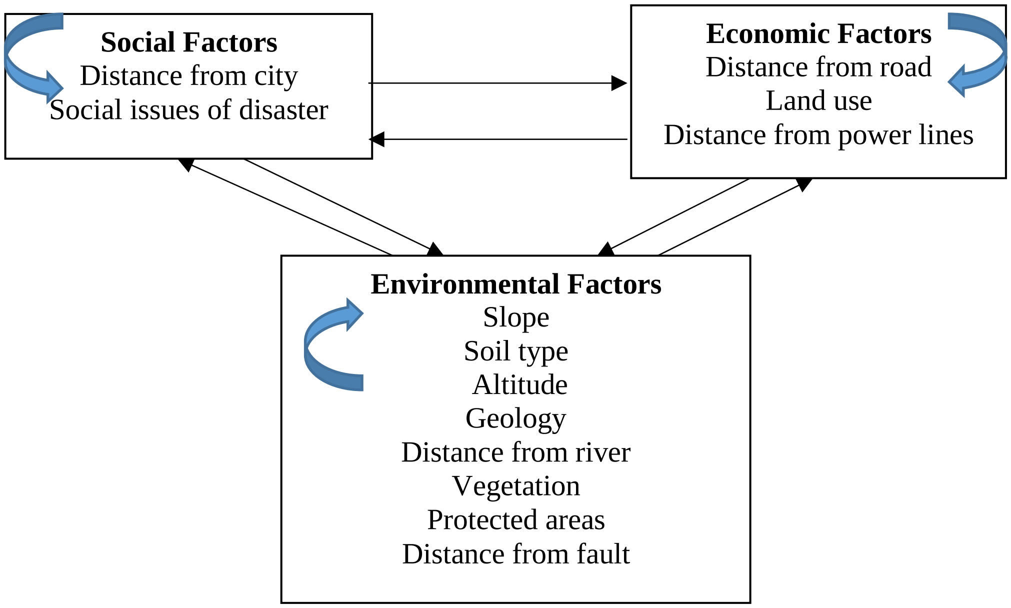

Fig. 2. Cluster model of factors affecting the location of industrial development in Azarshahr based on sustainable development principles

c) Forming super matrices and determining the final weight of criteria

In order to calculate the final factor, three types of super matrix were calculated including unweighted super matrix, weighted super matrix, and limited super matrix. Then, the final weight of these elements was investigated.

FUZZY STANDARDIZATION OF MAPS VIA GIS AND INTEGRATION BASED ON ANP WEIGHTS:

The first step often required the use of appropriate fuzzy scales, which were chosen according to the number and nature of variables. To convert normal numbers (i.e. numbers whose x values range from 0 to 1) to absolute values, a maximum and a minimum function were defined in Equation 1:

$$Max(X) = \mu \begin{cases} X & 0 \leq x \leq 1 \\ 1 & otherwise \end{cases} \quad (1)$$

$$Min(X) = \mu \begin{cases} 1 - X & 0 \leq x \leq 1 \\ 0 & otherwise \end{cases}$$

When the above functions were defined then the maximum value was cut with the right tolerance of the fuzzy number and the minimum value with the left tolerance of the fuzzy number. Thus, the left and right score values of the fuzzy number were obtained. This represented the level of importance of the fuzzy numbers ((x) ᴍ) at intersection points. The left and right points were represented by ((x) μ r) and (μ L (x)), respectively. The defined fuzzy domains have been represented in Figure 3 [22].

The fuzzy numbers based on the questionnaire defined scales have been shown in Table 2.

In order to analyze each criterion, firstly the current status of a required criterion was determined and converted in a raster map format. In the second step, each map was standardized to synchronize measurement units and converted them into comparable scales using the fuzzy method. Afterward, determining weights using ANP method was applied to integrate fuzzy maps by Raster Calculator tool in the GIS programming environment software. Finally, the fuzzy (continuous) map for industrial development appropriate areas was obtained. Therefore, layers of social criteria (including distance from city) were first

Fig. 3. Domains of fuzzy numbers

Table 2. Fuzzy numbers based on the questionnaire defined scales [22]

Row	Scale	Domain
1	Very weak	(0,0,0.1)
2	Weak	(0.05,0.2,0.35)
3	Average	(0.3,0.5,0.7)
4	Good	(0.65,0,75,0.95)
5	Excellent	(0.95,1,1)

combined based on their intrinsic ANP weights. Then, the economic and environmental criteria were compiled based on their intrinsic ANP weights. Accordingly, three maps based on the social, economic, and environmental criteria were designed. In the last step, final maps according to the ANP weights were obtained. The final map classification showed four distinct classes which were appropriate for industrial development [23].

RANKING SELECTED SITES WITH THE VIKOR TECHNIQUE:

The VIKOR method was first presented by Opricovic in 1998, and developed in 2002 [24]. Liu et al. applied VIKOR method to analyze failure modes in a fuzzy condition. The VIKOR method may provide a useful decision-making tool, particularly during difficulties that occur due to incompatible indices. The VIKOR method determines a compromise solution for decision-making. Because the mentioned procedure presented the maximum group desirability and minimum individual effects and attempts to choose the best optimal alternative which is so close to ideal answer [25]. In this study, after examining the obtained map, small and asymmetric sites were excluded. Finally, 12 suitable sites for development were selected. However, some industrial site location important parameters such as deep underwater table and wind direction could not be entered or overlaid as maps (data layers) in GIS. The selected options (sites) assessment showed that all 12 sites were located in the opposite direction of the prevailing wind [26]. Groundwater depth in the Urumia Lake relative to habitats and due to their placement in the flat plain of Urmia lake was about 15 meters. These criteria were same in all sites and ineffective based on VIKOR ranking. So, the prioritization of the 12 options was carried out based on the comparison of spatial pixel value of each option in the economic, social, and environmental map. Therefore, the location pixel value of each option was extracted from the GIS software; then, the VIKOR matrix was formed based on the 12 options and 3 criteria, and calculations were done in VIKOR Solver.

Classification according to the ANP method provides a powerful decision-making tool. The obtained results were usable to adopt appropriate measures for reducing economic and environmental costs. However, this method has some disadvantages. For example, ANP compares pairwise criteria and specifies the weight of each criterion, but it's unable to evaluate sub-criteria (in the current study, fuzzified criteria were entered to GIS).

Moreover, the ANP method determined a lot of criteria that didn't always propose a proper option due to the asymmetrical shape and lowlands. The GIS is a unique framework to apply various functions, analyze and change data, and combine different information layers for location applications. Therefore, conducting large-scale location studies in optimal time and accuracy would be impossible without using the GIS. One advantage of the GIS is the ability to exclude inappropriate lands for development, and conduct more detailed, faster, and less expensive studies in the remaining areas. It should be noted that unlike hierarchical or network decision-making models, the VIKOR technique does not use pairwise comparison.

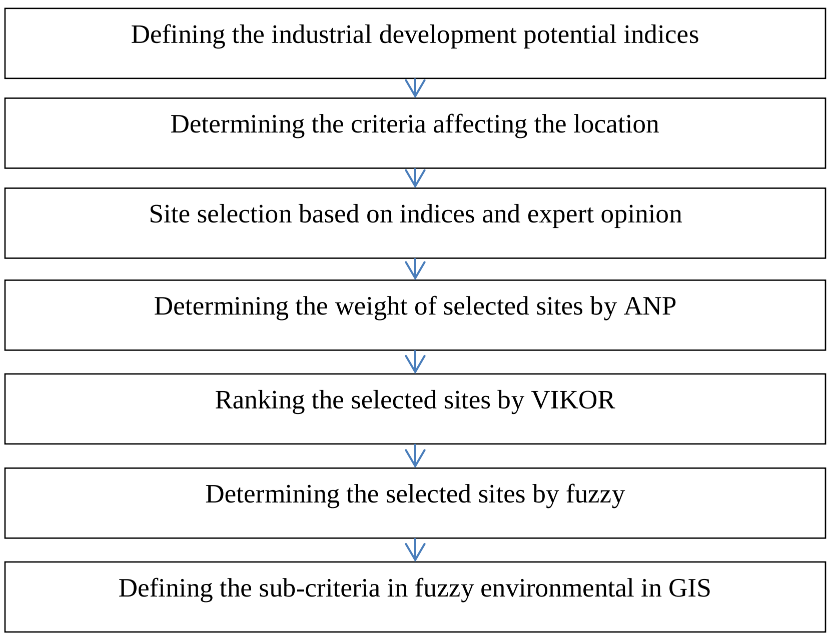

Fig. 4. Stages of the study

Instead, it assesses each option independently using a criterion [16]. The stages of this study were shown in Figure 4. As mentioned, the current study was aimed to identify and rank the industrial settlement development environmental factors in order to minimize adverse environmental impacts.

Contribution of the study:

In this study, the integrated decision-making model and GIS in the fuzzy environment were used to determine the parameters of Industrial Development. Hence, the parameters of industrial development potential in three areas of social development, economic development, environmental development, and natural disasters possibility in the region were considered.

RESULTS AND DISCUSSION:

The results of criteria ranking using ANP method showed that “distance from the city” criterion had the greatest weight (0.203) and “land use” criterion had the second greatest weight (0.134). The results of this section regarding each cluster have been presented in Table 3.

Standardized maps regarding hydrology conditions, distance from city, slope, and distance from power lines have been shown in Figures 5, 6, 7, and 8, respectively. Based on the results, it seemed that all sites were suitable for industrial development with regard to hydrology, slope, and distance from cities and power lines. In Figure 9, black spots represent the locations which were suitable for economic development because of defined criteria.

Ranking results obtained by VIKOR showed that site L was the first priority for establishing an industrial zone. The results obtained through solving VIKOR matrices were presented in Table 4; and the final ranking of options obtained by the VIKOR technique have been presented in Table 5.

Based on the results, the best sites for establishing industrial zones were located in the central and northwestern parts of the studied region. The northern, southern, and eastern parts of the studied area were inappropriate. The zone categorized as “suitable” had the smallest area among defined categories while the zone categorized as “average” had the largest area. According to the obtained results through overlaying the information layers, only 9% of the studied regions were appropriate and the conditions of the remaining 91% were either average or poor. The results of this section have been illustrated in Figure 10 and summarized in Table 6.

The selected site for industrial development was 1,800-hectares land located 8 km southwest of Azarshahr and 1.6 km north of Dashkasan village. The characteristics of this site have been presented in Table 7.

It could be concluded that the selected location were the best option considering different criteria such as optimal distance from town, having a vast area, accessibility (highways and railways), geological structure, mild slope, topography, and distance from agricultural and horticultural lands. This area located in a barren land and pastures with sparse vegetation while the current industrial town is located 6 km north of Azarshahr.

Ruiz et al. reported that industrial site location is one of the key steps in establishing an industrial unit as it has long-term and significant economic, environmental, and social effects. In this research, the parameters were investigated qualitative criteria regardless of their weights [2]. Aragonés-Beltrán et al. proposed the ANP method to select the best location for building a factory in the metropolitan area of Valencia. The results of their study showed that a proper investigation about the ecological potential in the development of metropolitan areas could be very effective to reduce pollution. The obtained results were in line with the results of the current study [15].

In another study, Rikalovic evaluated appropriate sites for industrial development using GIS and a multi-criteria decision-making method. This research which was conducted in Serbia showed that industrial site location was significantly important in the context of land use planning. Accordingly, the GIS and multi-criteria decision-making methods may facilitate this process and help reducing costs to a remarkable extent. In this research, only achieved rankings were defined as a buffer for GIS proximity analyses. The weight of each criterion was not included in determining the location and development of the industrial city [16].

Different studies evaluated qualitative criteria to find the best location. For example, Akkay et al. selected the best location for industrial, financial, health, and research centers based on different criteria such as economic, legal, software, desirability, and technological considerations [27]. They finally stated that the most important criteria for site selection were technological, financial, and software. Having considered these criteria, they proposed that the fuzzy system may provide a good approach to assess qualitative criteria. Similarly, the present study applied same logic but the employed criteria were different. In their study, social issues were the only assessed sustainable development factor, while satisfaction and environmental issues were ignored. The results of the current study, regarding industrial development potential were consistent with the results of Alikhani and Azar study. In their study, the researchers were interested in considering environmental aspects (similar to our study), and emphasized to use MCDM models to avoid the effect of opinions in the evaluation and determination of locations [28

Table 3. Final weights of criteria

Cluster	Weight	Sub-cluster	Weight
Environmental	0.374323	Distance from river	0.099
		Slope	0.081
		Altitude	0.073
		Distance from fault	0.037
		Soil type	0.024
		Geology	0.022
		Vegetation	0.009
		Distance from protected areas	0.008
Social	0.352045	Distance from city	0.203
		Social issues of disaster	0.125
Economic	0.273632	Land use	0.134
		Distance from power lines	0.090
		Distance from road	0.086

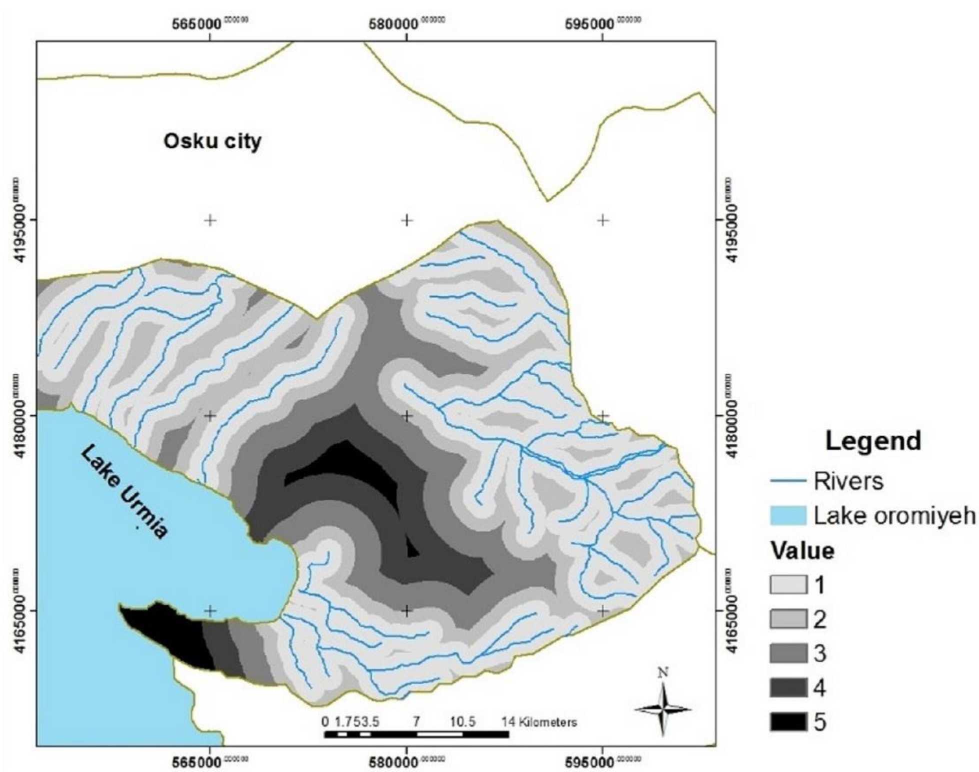

Fig. 5. standardized hydrology map

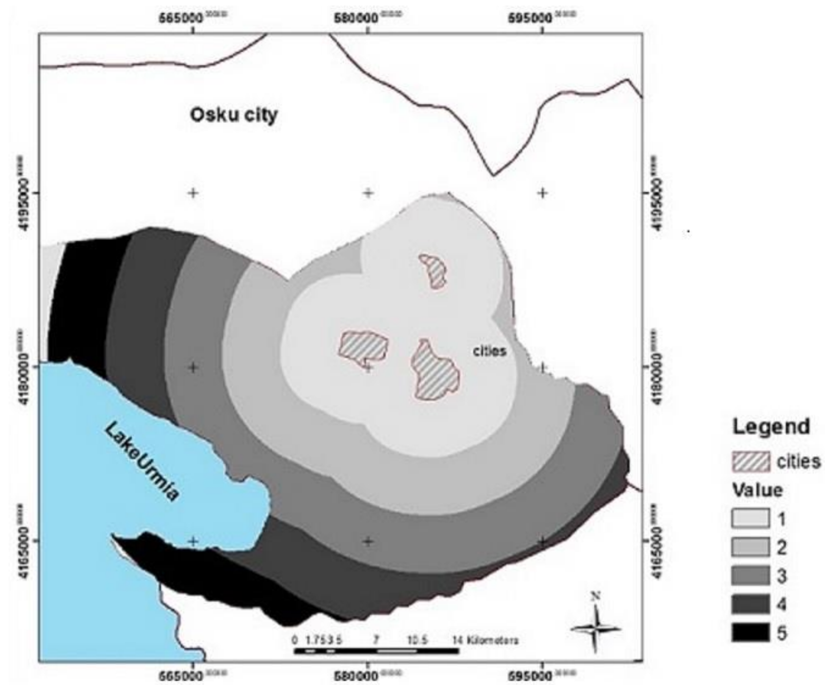

Fig. 6. Standardized map of distance from cities

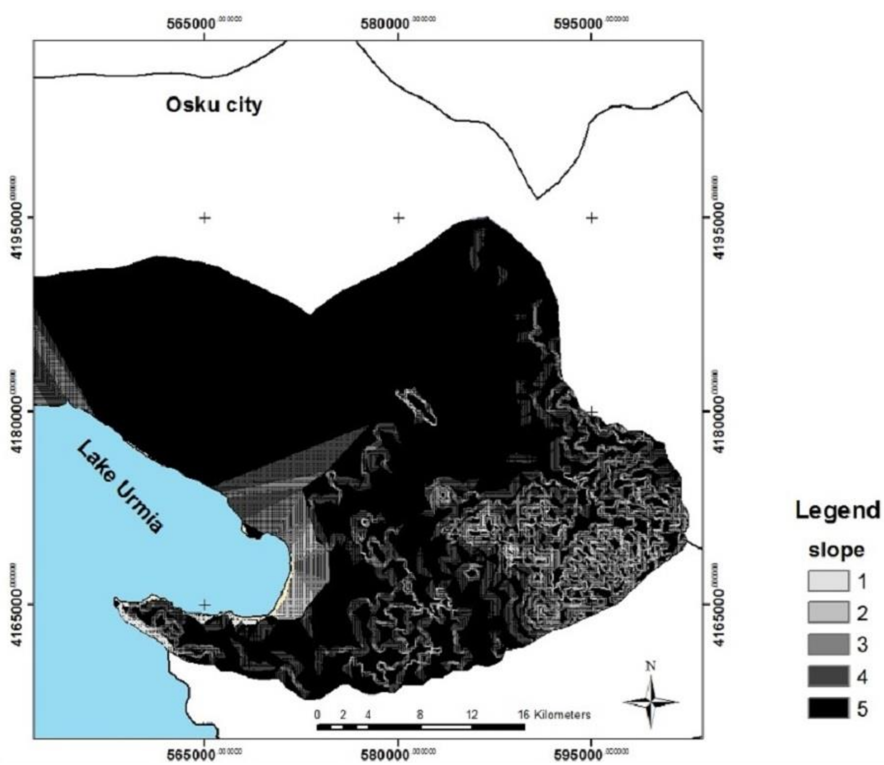

Fig.7. Standardized map of slopes

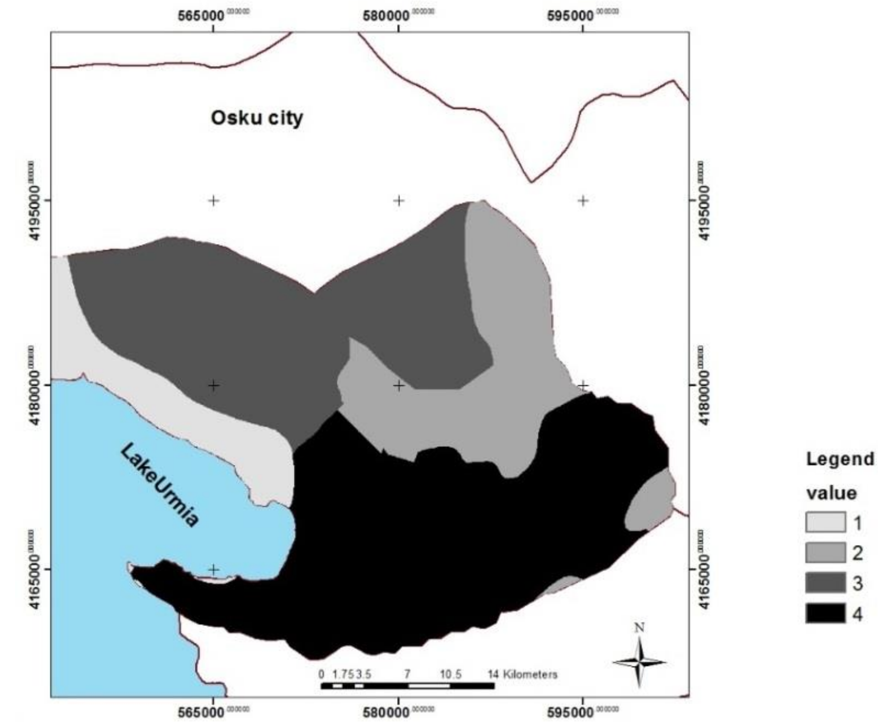

Fig. 8. Standardized map of distance from power lines

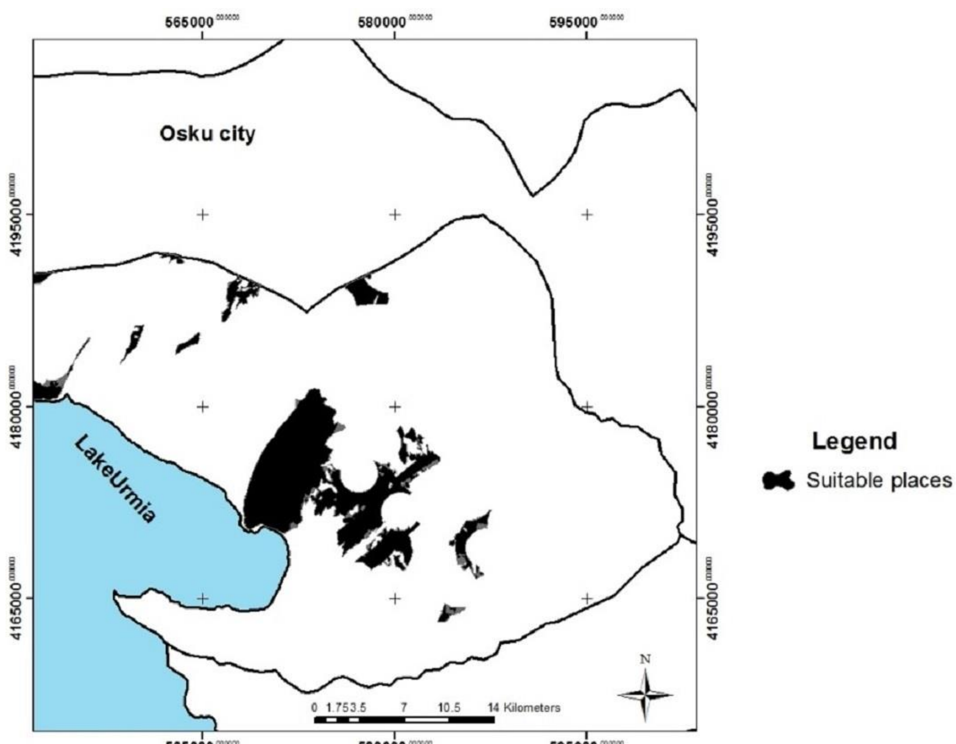

Fig. 9. Final map of the sites selected for industrial development

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Table 4. Matrix of desirability index/utility value (S) and inconsistency index/regret value (R)

Weight	**0.352045**	**0.273632**	**0.374323**	**S**	**R**
	Social criteria	Economic criteria	Environmental criteria		
A = 9	0.10214	0.064867	0.116586	0.335491	0.273633
B = 0	0.10214	0.080893	0.106044	0.269787	0.187699
C = 11	0.10214	0.087761	0.098629	0.276213	0.276213
D = 4	0.10214	0.083945	0.10667	0.225837	0.180227
E = 1	0.10214	0.080893	0.105151	0.280447	0.198359
F = 5	0.10214	0.083945	0.103811	0.259965	0.214355
G = 3	0.10214	0.074406	0.109618	0.304657	0.159621
H = 6	0.10214	0.080893	0.09041	0.456411	0.374324
I = 2	0.10214	0.064867	0.121768	0.273633	0.273633
J = 10	0.10214	0.084899	0.10399	0.246426	0.212218
K = 8	0.10214	0.077522	0.113192	0.224752	0.122378
L = 7	0.095793	0.079239	0.117033	0.510403	0.352023

Table 5. Ranking of selected options (sites) obtained by VIKOR technique

Site (option)	**K=8**	**D=4**	**B=0**	**G=3**	**J=10**	**F=5**	**E=1**	**I=2**	**C=11**	**9=A**	**H=6**	**L=7**
Q index	1	0.883	0.791	0.786	0.783	0.755	0.751	0.614	0.604	0.506	0.094	0.044
Rank	12	11	10	9	8	7	6	5	4	3	2	1

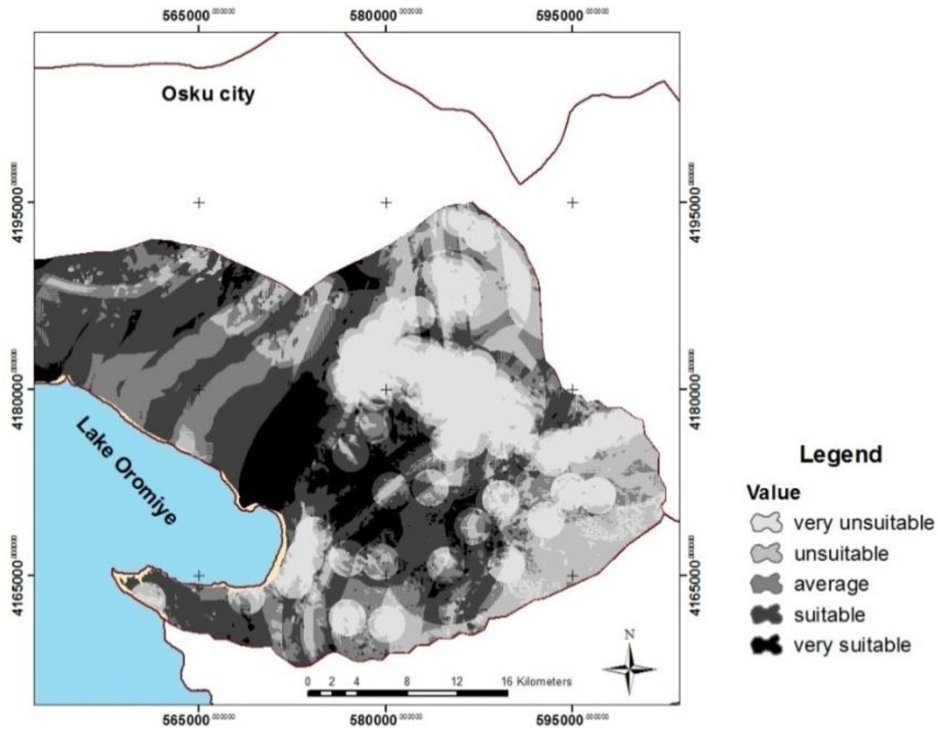

Fig.10. Desirability map obtained by compiling layers

Table 6. Zones with defined level of suitability for industrial development in Azarshahr

Row	Zone	Percentage of total area	Area (hectare)
1	Suitable	9	7561.28
2	Average	61	51243.16
3	Poor	17	14286.06
4	Very poor	13	10927.51

Table 7. Features of the selected site (distances in meters)

Title	Explanation	Title	Explanation
Name	Dashkasan	Distance from fault	6200
Coordinate X	575099 E	Lake Urmia	8000
Coordinate Y	4171212 N	Distance from main roads	1000
Altitude	1297	Distance from railways	1000
Average slope (%)	7	Groundwater depth	15
Area (hectares)	2800	Land use	Pasture with low vegetation
Distance from Azarshahr	8000	Geology	Terrace reserves/ sedimentary rock
Social issues of disaster	-	Soil type	Salty (loam soil)
Distance from protected areas	4000	Distance from airport	60000

CONCLUSION

The results of this study indicated the sustainable development criteria importance in evaluating agricultural land development potential. Furthermore, criteria such as distance from the river, distance from the fault, slope, distance from agricultural and horticultural, road accessibility, and distance from energy production centers had the greatest effects on the evaluation and selection of industrial development sites. The results also showed that environmental issues had a high score (0.374323) and should be duly considered by experts and authorities in the decision-making process. The current industrial town location comparison to the proposed location showed that the current location did not have any geographical similarity with the location determined by our study. In order to establish existing industrials towns, these important factors did not consider precisely and accurately. Therefore, this ignorance may expand or create different critical environmental problems in the future time.

The following errors may affect the results of the current study:

- Data inputting errors (including errors in base maps)
- Information processing errors (resulting from decision-makers and users)

Generally, investigating the quality of data inputting is necessary to reduce errors and optimize the results. Another source of error may happen due to incorrect decision-making and users' faults. To minimize these errors more relevant software and expert's knowledge are effective.

To the best of our knowledge, the integration of fuzzy GIS with ANP and VIKOR methods didn't implement in the previous studies. In addition, in this study, the assessment of the development capacity of industrial towns was evaluated using three socio-economic and environmental parameters. Finally, natural crises criterion was considered as a sub-criteria for the environmental criterion for the first time.

For future studies, it is recommended that the ANP technique based on logistics data will be used to acquire better consequences. In addition, it is suggested that other models for the compilation of base maps such as index overlaying and ordered weighted average will be applied to locate the industrial development sites.

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CONFLICT OF INTEREST

The author declares that there is no conflict of interests for any of authors. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy have been completely observed by the authors.

ABBREVIATIONS

ANP	Analytical Network Process
AHP	Analytical Hierarchy Process
FGIS	Fuzzy Geographic Information Systems
GIS	Geographic Information Systems
MCDM	Multi-Criteria Decision-Making
VIKOR	VlseKriterijuska Optimizacija I Komoromisno Resenje

REFERENCES

1 Forslid R., Haaland J., Midelfart K H. A U-shaped Europe? A simulation study of industrial location. *J. Int. Econ*. 2002; Vol.57, pp: 273–97.

2 Ruiz M.C., Romero E., Pérez MA., Fernandez I. Development and application of a multi-criteria spatial decision support system for planning sustainable industrial areas in Northern Spain. *Automation in Constr*. 2011; Vol. 22, pp: 320–333. https://doi .10.1016 /j. autcon.2011.09.009

3 Fernandez I., Ruiz M C. Descriptive model and evaluation system to locate sustainable industrial areas. *J. Clean. Prod*. 2009; Vol.17, pp: 87-100. https://doi.org/10.016/ j.jclepro.2008.02.011

4 Lorestani B., Yousefi N., Cheraghi M. Phytoextraction and phytostabilization potential of plants grown in the vicinity of heavy metal-contaminated soils: a case study at an industrial town site. *Environ. Monit. Assess*. 2013; Vol.185, p: 10217-10223. https://doi.org/10.1007/s10661-013-3326-9

5 Stuczynski T., Siebielec G., Korzeniowska-Puculek R. Geographical location and key sensitivity issues of post-industrial regions in Europe. *Environ. Monit. Assess*. 2009; Vol.151, pp: 77-91. https://doi.org/10.1007/s10661-008-0251-4

6 Omidvari M., Ghandehari M. Urban Environmental Management Performance Assessment by Fuzzy Analytical Hierarchy Processing (FAHP). *J. Environ. Accont. Manag*. 2014; Vol.2, pp: 31-41. [Persian] https://doi.10.5890/JEAM.2014.03.003

7 Pilouk S., Koottatep T. Environmental performance indicators as the key for eco-industrial parks in Thailand. *J. Clean. Prod*. 2017; Vol. 156, pp: 614-623. https://doi.org /10. 1016/ j.jclepro.2017.04.076

8 Liu Z., Adams M., Raymond P., Yong Geng C., Chen Q., Liu W., Sun L., Yu X. Comprehensive development of industrial symbi osis for the response of greenhouse gases emission mitigation: Challenges and opportunities in China. *Energy. Policy*. 2017; Vol.102, pp: 88-95. https://doi.org/10.1016/j.enpol.2016.12.013

9 Parajuli I., Lee H. Study on integration techniques for Environmental Impact Assessment of different media based standard industrial classification: A case study of South Korea, *J. Clean. Prod*. 2017; Vol.151, pp: 643-651. https://doi.org/10.1016/j.jclepro.2017.03.012

10 Navaie aznave Z., Omidvari M. Safety Risk assessment in Motor vehicle industries by using William fine and ANP-DEMATEL. *ioh*. 2017; Vol.14 (1), pp: 57-70. http://ioh.iums.ac.ir/article-1-1643-fa.html

11 Shahabi S., Salehi A., Seifolahi M. Investigation of the Factors Influencing the success of Rural Industries in Employment Generation (Case Study: Isfahan Province). J. Res. Rural. Plan. 2015; Vol.4, pp: 9-11.

12 Madadi M. Evaluation of location of industrial towns of Chaharmahal and Bakhtiari Province case study: Shahhrekord Industrial town, MS Thesis, University of Tabriz. 2003. [Persian]
13 Ahadnezhad M., Zolfi A., Norouzi Mj. An analysis of the location of land to establish industry using AHP & VIKOR methods (Case study: central section of Aras free zone), *Environ. Based Territorial Plann.* (AMAYESH). 2013; Vol.7, pp: 63-82. [Persian]
14 Dalir F., Shafiepour Motlagh M., Ashrafi K. Sensitivity analysis of parameters affecting carbon footprint of fossil fuel power plants based on life cycle assessment scenarios. *Global J. Environ. Sci. Manage*. 2016, Vol.3 (1), pp: 75-88. https://DOI.10.22034/gjesm.2017.03.01.008
15 Aragonés-Beltrán P., Ferrandoa J., García F., Agullóa A. An Analytic Network Process approach for siting a municipal solid waste plant in the Metropolitan Area of Valencia (Spain). *J. Environ. Manage*. 2010; Vol.91, pp: 1071-86. https://doi.org/10 .1016 /j.jenvman.2009.12.007
16 Rikalovic A., Cosic I., Lazarevic D. GIS Based Multi-Criteria Analysis for Industrial Site Selection. *Procedia Eng*. 2014; Vol. 69, pp: 1054-1063. https://DOI:10.1016 /j.proeng .2014.03.090
17 Liu H.C., Liu L., Mao L.X. Risk evaluation in failure mode and effects analysis with extended VIKOR under fuzzy environment. *Expert. Syst. Appl*. 2012; Vol.39, pp: 12926-12934. https://doi.org/10.1016/j.eswa.2012.05.031
18 Park JM., Park J.Y., Park H.S. A review of the National Eco-Industrial Park Development Program in Korea: progress and achievements in the first phase, 2005–2010. *J. Clean. Prod*. 2016; Vol.114, pp: 33-44. https://doi.org/10. 1016/ j.jclepro. 2015.08.115
19 Geng Y., Fujita T., Park HS., Chiu ASF., Huisingh D. Progress on innovative eco-industrial development. *J. Clean. Prod*. 2016; Vol.114, pp: 1-10. https://doi.org/ 10. 1016/j.jclepro.2015.09.051
20 Chung SH., Lee AH L., Pearn WL. Analytic network process (ANP) approach for product mix planning in semiconductor fabricator. *Int. J. Prod. Econ*. 2005; Vol. 96, pp: 15–36. https://doi.org/10.1016/j.ijpe.2004.02.006
21 Saaty R W. Decision making in complex environment: The analytic hierarchy process (AHP) for decision making and the analytic network process (ANP) for decision making with dependence and feedback. Pittsburgh: Super Decisions. 2003.
22 Zhao R., Govind R. Defuzzification of fuzzy intervals. *Fuzzy Set Syst*. 1991; Vol.43, pp: 45–55.
23 Grekousis G., Manetos P. Photis YN. Modeling urban evolution using neural networks, fuzzy logic and GIS: The case of the Athens metropolitan area. Cities. 2013; Vol.30, pp: 193-203. http://dx.doi.org/10.1016/j.cities.2012.03.006
24 Opricovic S., Tzeng G. H. Extended VIKOR method in comparison with outranking methods. *Eur. J. Oper. Res*. 2007; Vol.178, pp: 514–529. https://doi.10.1016 /j.ejor .2006.01.020
25 Opricovic S., Tzeng G.H. Multi-criteria planning of post-earthquake sustainable reconstruction. *Comp. aided civil and infrastructure. eng*. 2002; Vol.17, pp: 211-220. https://doi.org/10.1111/1467-8667.00269
26 Ruiz P., Fernández I., Ortiz JJ, Pérez A., Fernández P. The Development of a New Methodology Based on GIS and Fuzzy Logic to Locate Sustainable Industrial Areas, 10th AGILE International Conference on Geographic Information Science 2007 Aalborg University, Denmark.2007.
27 Akkaya G., Turanoğlu B., Öztaş S. An compiled fuzzy AHP and fuzzy MOORA approach to the problem of industrial engineering sector choosing. *Expert. Syst. Appl*. 2015; Vol.42, pp: 9565–9573. https://doi.org/10.1016/j.eswa.2015.07.061
28 Alikhani R., Azar A. A hybrid fuzzy satisfying optimization model for sustainable gas resources allocation. *J. Clean. Prod*. 2015; Vol.107, pp: 353–365. https://doi.org/ 10.1016/j.jclepro.2015.01.064