Social and Economic Geography, 2015, Vol. 1, No. 1, 44-54
Available online at http://pubs.sciepub.com/seg/1/1/7

DOI:10.12691/seg-1-1-7

A Multi-criteria Group Decision Making Approach for Rural Industrial Site Selection Using Fuzzy TOPSIS in Central Iran

Abbas Amini*

Department of Geographical Sciences and Planning, University of Isfahan, Isfahan, Iran
*Corresponding author: a.amini@geo.ui.ac.ir, komsh1@yahoo.com

Received April 15, 2015; Revised May 05, 2015; Accepted May 10, 2015

Abstract Industrialization, beside the agriculture, is the most important alternative to diversify of rural economy and generate income and employment opportunities, especially in Third World. Appropriate location allocation for rural industrialization is the most feature of industrial decentralization towards regional and rural development. It needs considering uncertain criteria and conditions, which are often required to deal with subjective and imprecise assessments representing by fuzzy data. Using fuzzy TOPSIS methodology in a group decision-making context, the purpose of this article is to evaluate the rural industrial site selection in a central province of Iran. The procedure involves identification of potential locations, selection of evaluation criteria, use of fuzzy theory to quantify criteria values under uncertainty and evaluation and selection of the best location for implementing rural industrial sites. Applying the procedure on the set of 15 rural industrial sites of the study area, which 11 of them are operant and the else 4 ones are candidate to establish, revealed some in optimalities in selection of the sites. Although the first orders belong to some of the operant sites, some of the others have also last orders, whereas some of the candidate sites have the better situations and upper priorities. Therefore, the rational proceeding of the industrialization procedure in the rural study area entails some revisions in deciding and policy making for both of the operant and candidate rural industrial sites at the future.

Keywords: *rural industrialization, location analysis, multi-criteria decision-making, group decision making, fuzzy TOPSIS*

Cite This Article: Abbas Amini, "A Multi-criteria Group Decision Making Approach for Rural Industrial Site Selection Using Fuzzy TOPSIS in Central Iran." *Social and Economic Geography*, vol. 1, no. 1 (2015): 44-54. doi: 10.12691/seg-1-1-7.

1. Introduction

1.1. Rural Industrialization and Poverty Alleviation

Increasing population growth and low productivity rate of agriculture accompanied by decline of water resources and potential drought regions, especially in developing countries, conducted to some fundamental changes in the economical structure of rural communities. In many cases, the neglect of rural areas and the resulting high poverty levels against a background of urban industrial development led to increasing rates of rural-urban migration. Five major effective approaches which mentioned and emphasized in literatures to poverty alleviation, called "Big Five", includes foreign aid, microfinance, social entrepreneurship, base of the pyramid initiatives, and the establishment of property rights (e.g., Bruton et al., 2011; Prahalad, 2006; Sachs, 2005). Nevertheless, as the Alvbarez et al. (2015) have clarified in their empirical and comparative study on some developing countries, despite the some benefits of these approaches, none has fulfilled their promise ofpoverty alleviation and the international industrialization has comparatively had a more significant impact on poverty alleviation in at least some countries. Considering the fact that these efforts may simply not have the impact on poverty that opening a new manufacturing plant can, they argue that if we seek to fulfill our promises of poverty alleviation and to end needless human suffering, industrialization is the key and needed to finally obtain the goal of abject poverty alleviation (Ibid).In fact,the existence of wide income disparities has been, and still is, the fundamental drive for rural people to migrate to cities(Song et al., 2012).

Generation of rural nonfarm employment for the poor has emerged as an important rural development policy topic, given that the scope for increasing jobs in agriculture is limited(Simmons & Supri, 1997) and also the demand for farm labor by commercial farms is waning over time (Corral &Reardon, 2001). Therefore, the contribution of small and medium sized industrial enterprises is inevitable in order to revitalize the rural economy (North & Smallbone, 1996), specially due to the impossibility of large scale industrialization to developing economies, because of resources constraints (Tesfayohannes and Temtime, 2002).Over the last five decades, for example, China and India have made dramatic improvements in their standard of living and structural transformation of the rural economy. Industries and services now form an integral part of the output and employment of the rural sector. The share of agriculture in total GDP has declined to less than one-third in India and about one-seventh in China. This transition is remarkable considering the initial situation in the two countries half a century ago (Mukherjee & Zhang, 2007).Epstein & Jezeph (2001), have studied the rural areas of India and Thailand comparatively and introduced a rural-urban partnership development paradigm as another way of development, based on the rural industrialization.

The widespread and great inequalities in income generation, commonwealth, job opportunities and developmental facilities between urban and rural areas in Iran, have leaded the rural population towards the decline and in some instances the rural exodus. Additionally, the rural poverty and deprivation has also caused major urban crisis, due to the vast rural migration and consequently the suburbia phenomena. The agricultural sector in Iran rural economy is not able to meet all of the economical necessities towards the rural development. The rural industrialization can considered as the most important non-farm economical activities and the second major alternative in Iran rural economy, as well as the other developing countries (Shrifonnasabi, 1986; Gharanejad, 1993). The rationale of the rural industrialization is therefore the necessity to (Tangamuthu, 1992; Sharma et al, 2006): a) reduce the rural-urban economical imbalances and inequalities, b) avoid and mitigate the social costs of irregular urbanization or in the other word, urban sprawl phenomena, and c) provide appropriate and profitable employment opportunities for rural over plus labor forces.

1.2. Rural Industrialization and Location Allocation

It has often cited in the literature that the growth of rural industries in less developed countries is more a sign of rural poverty than a sign of rural development, since the poor undertake these activities mainly as a last resort (Tambunan, 1995). As the Shen (1999) noted, this can lead to a highly unbalanced spatial distribution and an increase in inequality of rural industrial development, due to none considering of locational prerequisites. Industrialization, urbanization, original economic basis, and location are four major driving forces of the disparity of rural area development (Liu et al., 2013) and Undoubtedly, as the Song et al. (2012) clarified, it is a fact that some rural areas have a better access to urban technology than others have, and thus are more likely to embrace rural industrialization. Therefore, the location of rural industries and its optimality is of the most important and essential issues of the rural industrialization process, which can effectively conduct the process to meet the economical, social, environmental and spatial equities successes. Generally, one of the most important and unavoidable dimensions for developmental planning nowadays, is locational or spatial dimension in addition to the economical and social aspects. In fact, considering this complementary point, assures that the developmental practices do not reduced to only economical growth. This helps that developmental consequences and benefits distributed more appropriate and mitigate the regional inequalities, especially in remote rural areas. Thus, the precisely designed and optimal establishment of industrial sites (in scale, type and location) in rural regions can play the same role, which enabled the China's government to fundamentally transform its rural economy in 1980 decade: "leave the land not the countryside, enter the factory but not the city" (Mei, 1993). In this regard and more in detail, the Chinese government has fostered the development of Town-and-Village Enterprises (TVEs), the aim of which was to promote the industrialization of rural areas by making the farmers “leave their rice-fields without leaving hometown” and “move to manufactories without moving into cities” (song et al., 2012). The approach by which the rural share in Chinese manufacturing output grew from 14.3% in 1980 to 70.4% in 2002 and shows that such firms have been able to absorb or create jobs away from big cities (Ibid).This approach has also an important role in regional development planning by facilitating of the industrial decentralization procedures. Additionally, as mentioned by Yildirim and Yilmaz (2005), wrong decisions on land-use have caused degradation and destruction of the environment and natural resources. In this regard, the claim of Khadka and Shrestha (2011) is also considerable that the most of South Asian Sub-Continent countries have exposed to many environmental problems due to the intensification of industrialization and urbanization.

1.3. Fuzzy TOPSIS as a Location Evaluation Method

TOPSIS is a technique for order preference by similarity to ideal solution proposed by Hwang & Yoon (1981). This approach chooses the alternative that is closest to the positive ideal solution and farthest from the negative one (Gligoric et al., 2010; Awasthi et al., 2011). In the classical TOPSIS method, the weights of the criteria and the ratings of alternatives known precisely and crisp values used in the evaluation process. Under many conditions, crisp data are inadequate to describe real situations. In such cases, the fuzzy TOPSIS method is proposed where the weights of criteria and ratings of alternatives evaluated by linguistic variables represented by fuzzy numbers.There are many applications of fuzzy TOPSIS in the location analysis literature. For instance, Chen (2000) extended the TOPSIS to the fuzzy environment and gave numerical example of system analysis engineer selection for a software company. Chu (2002) presented a fuzzy TOPSIS model under group decisions for solving the facility location selection problem. Yang & Hung (2007) proposed to use TOPSIS and fuzzy TOPSIS methods for plant layout design problem. Gligoric et al. (2010) applied fuzzy TOPSIS method and network optimization in order to Shaft location selection at deep multiple orebody deposit. Fuzzy techniques used in this study to incorporate data related to ore reserve and costs into shaft location problem. Kuo et al. (2007) presented a new method of analysis of multi-criteria based on the incorporated efficient fuzzy model and concepts of positive ideal and negative ideal points to solve decision-making problems with multi-judges and multi-criteria in real-life situations. A numerical location selection example has illustrated to demonstrate the applicability of the method, with its simplicity in both concept and computation. Ekmekcioglu et al. (2010) also modified the fuzzy TOPSIS methodology and applied it for the selection of appropriate disposal method and site for municipal solid waste. Awasthi et al. (2011) developed a multi-criteria decision making approach and used the fuzzy TOPSIS method to evaluate and select the best location for implementing an urban distribution center. Chamodrakas et al. (2009) applied a new class of fuzzy methods for evaluating customers is. The issue of uncertainty of customer evaluation and involved qualitative criteria tackled by employing the fuzzy TOPSIS method in order to efficiently transform linguistic assessments into crisp numbers and integrate the behavioral pattern of the decision maker into its principle of compromise.

There exist 11 operant industrial sites (each site comprises several manufactories and workhouses) and four candidate locations to establish the industrial sites in the rural areas of the Markazi province, located at the central of Iran. This province has the first order in rural industrial sites around the country (Markazi Office of Government General, 2009). The purpose of the present study is a spatial assessment about the distribution of these industrial sites. In other word, the locational appropriateness and optimality of the carried out proceedings as for rural industrialization in the region investigated if there is or not. To this purpose a multi-criteria decision making framework has been employed in fuzzy environment and the problem has been formulated and solved using fuzzy TOPSIS approach.

2. Materials and Methods

2.1. Basic Concepts

Before the description of fuzzy TOPSIS, a brief discussion is required on the concepts of fuzzy sets, linguistic variables, fuzzy numbers and some primary fuzzy mathematical operations over them. Some related definitions presented as follows.

2.1.1. Basics of Fuzzy Sets Theory

In order to deal with the vagueness of human thought, Zadeh (1965) first introduced the fuzzy set theory. This theory was oriented to the rationality of uncertainty due to imprecision or vagueness. A fuzzy set is a class of objects with continuum of grades of membership. Such a set characterized by a membership function, which assigns to each object a grade of membership ranging between zero and one. In other words, an element may partially belong to a fuzzy set (Gligoric et al., 2010). The role of fuzzy sets is significant when applied to complex phenomena not easily described by traditional mathematical methods, especially when the goal is to find a good approximate solution (Bojadziev & Bojadziev, 1998). Modeling using fuzzy sets has proven to be an effective way of formulating decision problems where the information available is subjective and imprecise (Zimmermann, 1992). A sign "~" will be placed above a symbol if the symbol represents a fuzzy set (Gligoric et al., 2010).

2.1.2. Linguistic VARIABLES

A linguistic variable is a variable whose values are words or sentences in a natural or artificial language (Zadeh, 1975). In other words, variables, whose values given in linguistic terms, i.e. words, sentences, etc., called linguistic variables (Chen, 2001; Li, 2007; Lin & Chang, 2008; Yong, 2006). As an illustration, the ratings of alternatives on qualitative criteria could be expressed using a linguistic variable with values such as good, poor, etc. (Chamodrakas et al., 2009). In this paper, the weights of criteria and the ratings of qualitative criteria expressed as linguistic variables. In fuzzy set theory, conversion scales applied to transform the linguistic terms into fuzzy numbers. A scale of 1–9 applied for rating the criteria and the alternatives. Table 1 presents the linguistic variables and respective fuzzy triangular numbers for weighting criteria and Table 2 presents the linguistic variables and respective transformations to fuzzy numbers for ratings the alternatives (rural industrial sites) against the evaluation set of criteria. In fact, the concept of a linguistic variable provides a means of approximate characterization of phenomena, which are too complex to be amenable to description in conventional quantitative terms (Zadeh, 1975).

Table 1. Linguistic variables for criteria weights and transformation to triangular fuzzy numbers

Linguistic terms	Membership function
Very low (VL)	(1, 1, 3)
Low (L)	(1, 3, 5)
Medium (M)	(3, 5, 7)
High (H)	(5, 7, 9)
Very high (VH)	(7, 9, 9)

Table 2. Linguistic variables for alternative ratings and respective triangular fuzzy numbers

Linguistic terms	Membership function
Very poor (VP)	(1, 1, 3)
Poor (P)	(1, 3, 5)
Fair (F)	(3, 5, 7)
Good (G)	(5, 7, 9)
Very good (VG)	(7, 9, 9)

2.1.3. Fuzzy Numbers

Many researchers have used linguistic assessments and their expression as fuzzy numbers in order to model both criteria weights and evaluation data related with subjective/qualitative criteria (Chen, 2001; Li, 2007; Lin & Chang, 2008; Yong, 2006).Fuzzy numbers are a subset from the real numbers set, representing the uncertain values. Triangular fuzzy numbers (TFN) are very convenient to work with because of their computational simplicity in fuzzy environments. In this paper it is emphasized the TFNs for using in the fuzzy TOPSIS method. Triangular fuzzy numbers can be defined as a triplet (a, b, c). The parameters a, b and c respectively, indicate the smallest possible value, the most promising value and the largest possible value that describe a fuzzy event (Gligoric et al., 2010). A fuzzy triangular number $\tilde{M}$ shown in Figure 1.

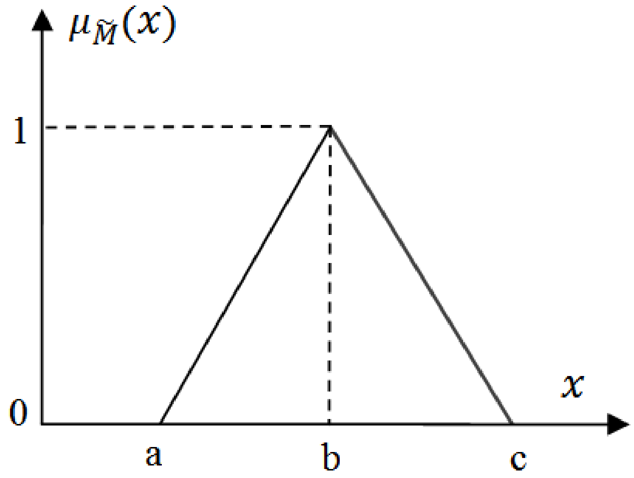

Figure 1. Triangular fuzzy number

The relevant membership function of the TFN given by (Kaufmann & Gupta, 1985):

$$\mu_{\tilde{M}}(x)=\begin{cases}0, & x<a\\ \dfrac{x-a}{b-a}, & a\le x\le b\\ \dfrac{c-x}{c-b}, & b\le x\le c\\ 0, & x>c\end{cases} \quad (1)$$

The basic fuzzy arithmetic operations on two triangular fuzzy numbers $\tilde{A}=(a_1,a_2,a_3)$ and $\tilde{B}=(b_1,b_2,b_3)$ are defined as follows: inverse: $\tilde{A}^{-1}=(1/a_3, 1/a_2, 1/a_1)$, addition: $\tilde{A}\oplus\tilde{B}=(a_1+b_1, a_2+b_2, a_3+b_3)$, subtraction: $\tilde{A}\ominus\tilde{B}=(a_1-b_3, a_2-b_2, a_3-b_1)$, scalar multiplication: $\forall k>0, k\in R, k.\tilde{A}=(k.a_1, k.a_2, k.a_3)$, multiplication: $\tilde{A}\otimes\tilde{B}=(a_1.b_1, a_2.b_2, a_3.b_3)$, division: $\tilde{A}\oslash\tilde{B}=(a_1/b_3, a_2/b_2, a_3/b_1)$.

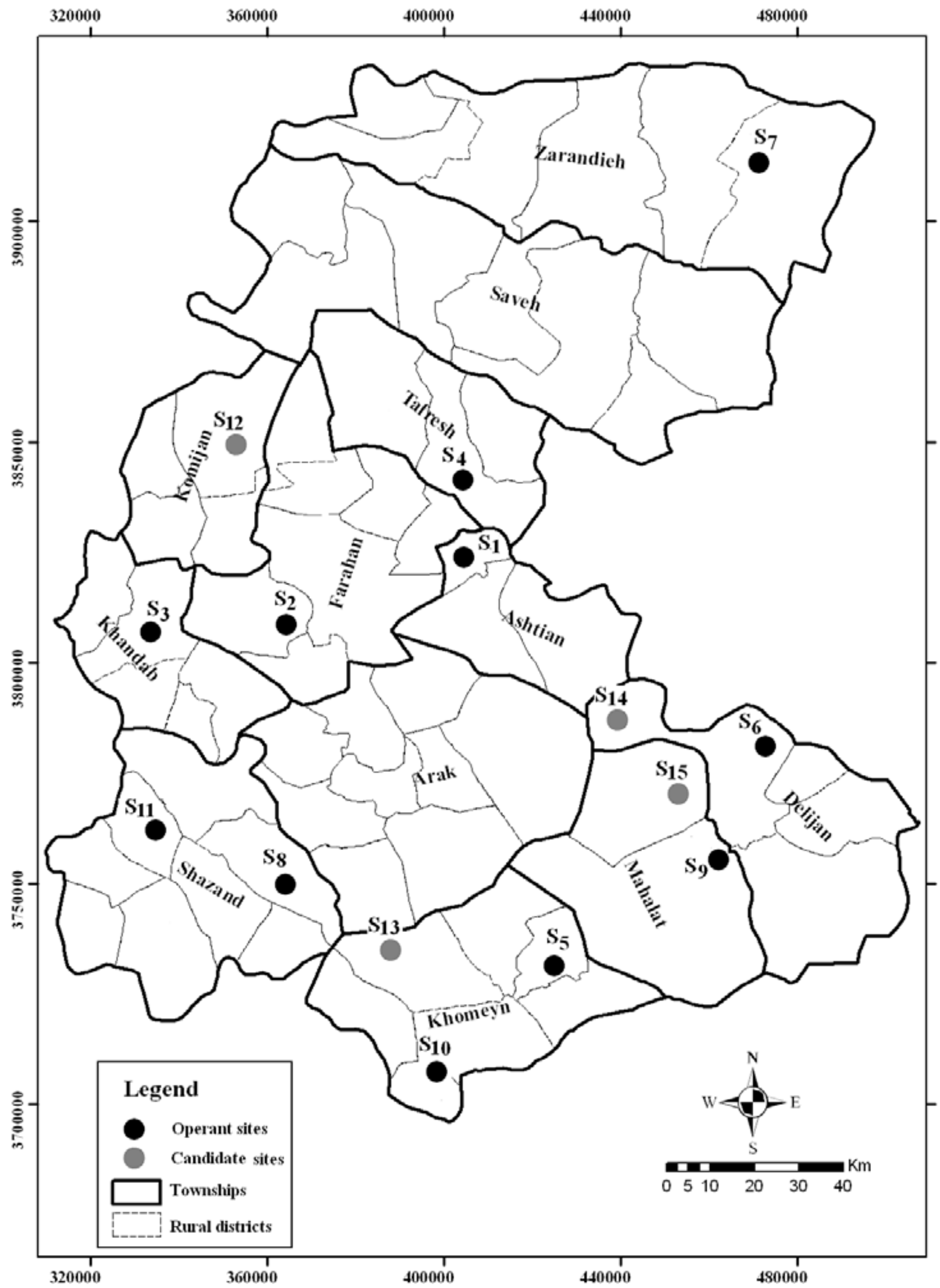

Figure 2. Study area, operant and candidate locations for rural industrial sites

2.2. Study Area (Alternative Locations)

The study region is rural areas of Markazi province in central Iran with the capital of Arak city. The region is situated between the north latitudes of 33º 23′ to 35º 33′ and east longitudes of 48º 56′ to 51º 03′, covering an area of 29127 km^2 (Figure 2). It is located in the semi-desert and mountainous temperate climates, with mean annual temperature range of 4 - 18º C and annual rainfall ranging between 170 and 450 mm. The elevation of the region varies within the range of 950 - 3388 m above sea level (Markazi Office of Government General, 2009). The province comprises 1273 villages distributed in 62 rural districts of 11 townships. The rural population of the region is 432404 (about 32 percent of total population), of which about the employment rate in industry is 34 percent. The industrial employment rate of whole province is also 35.6 percent (Ibid).As the most of the Iranian villages are sparse, small and located in remote rural areas, without so skilled force and infrastructure, industrializing such rural areas needs to focus on some selected rural regions more ensuring the economical success of the operation. Choosing such potential locations entails the exact evaluation and analysis of the possibilities and relative advantages. A rural district seems the best spatial analysis unit for such studies. The province containing 11 operant and four candidate rural industrial sites, represented by back and grey symbols in Figure 2 respectively. Total coverage of the operantsites is 218 ha including 498 industrial manufactory and workhouses, which has estimated that generate about 3086 job opportunities for 100426 rural population of 172 covered villages (Ibid). Figure 2 shows the location and spatial distribution of these operant and candidate industrial rural sites.

Table 3. Evaluation criteria and the experts' linguistic assessments for their weights (relativeimportances).

Evaluation criteria	Type	Decision makers				
		D_1	D_2	D_3	D_4	D_5
C_1Climatic situations (temperature, weather, dominant wind direction, etc.)	Benefit	M	M	M	M	M
C_2Landform and geomorphologicsituations	Benefit	VH	VH	VH	VH	H
C_3Water resources availability (surface and groundwater)	Benefit	VH	VH	VH	VH	VH
C_4 Future expansion possibility	Benefit	VH	H	H	H	H
C_5 Accessibilities (road, transportation, etc.)	Benefit	VH	VH	VH	H	H
C_6 Infrastructures (communications, industrial power, etc.)	Benefit	VH	VH	VH	H	VH
C_7 Security (from accidents, theft and vandalism)	Benefit	L	M	VH	M	H
C_8 Costs (in acquiring land, vehicle, drivers and taxes)	Cost	M	H	H	H	M
C_9 Resources availabilities (raw materials, labor forces, etc.)	Benefit	M	H	H	H	M
C_{10} Proximity (to customers and suppliers)	Benefit	M	H	H	VH	L
C_{11}Environmental impacts (on the air, water and soil pollution, noise, etc.)	Cost	VH	M	VH	VH	H

Table 4. Linguistic ratings; group assessments of alternatives (rural industrial sites) against evaluation criteria ($\tilde{x}_{ijk}$)

Sites	Evaluation criteria (D_k: D_1, D_2, D_3, D_4, D_5)					
	C1	C_2	C_3	C_4	C_5	C_6
$S_1(O_1)$	F,G,G,G,VG	F,P,G,F,P	F,VP,VP,P,F	VP,P,F,F,P	G,F,P,F,F	F,P,P,F,F
$S_2(O_2)$	G,F,VG,G,VG	G,F,G,VG,VG	G,P,G,G,G	G,F,G,VG,G	G,F,F,F,F	G,P,F,G,F
$S_3(O_3)$	G,G,G,VG,VG	G,F,G,G,F	F,G,G,G,G	G,P,F,G,G	G,F,P,F,F	G,F,F,G,F
$S_4(O_4)$	G,G,VG,G,VG	F,P,P,P,F	G,P,P,G,G	F,P,VP,P,P	G,P,F,F,F	G,F,G,F,F
$S_5(O_5)$	G,G,VG,G,VG	F,VG,VG,VG,VG	F,P,F,P,F	F,G,VG,G,VG	F,F,F,G,G	G,F,G,F,F
$S_6(O_6)$	F,G,VG,G,VG	G,G,G,G,G	G,P,G,G,G	G,F,F,G,G	F,G,G,G,VG	G,G,F,G,G
$S_7(O_7)$	G,G,VG,F,VG	G,G,VG,G,VG	F,P,G,P,G	G,P,VG,G,VG	G,F,VG,VG,VG	G,G,G,FG
$S_8(O_8)$	F,VG,G,VG,VG	F,G,G,G,VG	G,P,G,VG,F	G,P,VP,G,G	G,F,P,G,G	G,G,G,VG,F
$S_9(O_9)$	F,VG,G,F,VG	F,F,G,F,VG	F,P,F,F,F	G,F,VG,F,G	F,F,G,G,G	G,G,G,F,F
$S_{10}(O_{10})$	F,F,VG,VG,VG	F,P,P,G,G	F,P,F,G,G	F,F,VP,G,F	F,P,VP,F,F	F,P,P,G,F
$S_{11}(O_{11})$	F,G,G,G,VG	F,G,F,F,F	F,P,F,VG,G	P,P,P,F,F	F,G,F,G,G	F,F,F,G,F
$S_{12}(C_1)$	G,VG,G,G	G,VG,G,G	G,G,G,F	F,P,P,P	G,F,F,F	VP,VP,VP,VP
$S_{13}(C_2)$	G,VG,VG,VG	G,G,VG,VG	F,G,F,F	G,VG,VG,VG	G,VG,VG,VG	VP,VP,VP,VP
$S_{14}(C_3)$	VG,VG,VG,VG	VG,G,VG,VG	F,F,G,G	G,G,F,G	F,G,F,F	G,F,G,F
$S_{15}(C_4)$	G,G,G,G	G,G,F,G	F,F,F,F	G,F,G,G	F,G,F,F	VP,VP,VP,VP

Sites	Evaluation criteria (D_k: D_1, D_2, D_3, D_4, D_5)				
	C_7	C_8	C_9	C_{10}	C_{11}
$S_1(O_1)$	G,G,F,VG,G	F,F,VP,P,P	G,P,F,F,F	F,P,VP,F,P	F,F,F,G,G
$S_2(O_2)$	G,F,G,VG,G	G,F,F,G,G	G,P,F,G,F	F,F,P,F,F	G,F,F,G,G
$S_3(O_3)$	G,G,G,VG,G	G,F,F,G,G	G,F,F,G,G	G,F,P,F,F	G,F,F,G,F
$S_4(O_4)$	G,F,G,VG,G	G,F,F,P,F	F,P,F,G,F	F,P,P,F,F	G,F,F,G,F
$S_5(O_5)$	G,G,G,VG,G	F,F,G,G,F	G,F,F,F,G	F,F,F,G,F	F,G,G,G,G
$S_6(O_6)$	G,G,G,VG,G	G,F,F,F,G	G,G,G,G,G	G,F,G,G,G	G,G,G,G,G
$S_7(O_7)$	G,G,G,VG,G	G,F,F,F,G	VG,F,VG,F,G	VG,G,VG,VG,VG	G,G,G,G,F
$S_8(O_8)$	G,G,G,VG,G	G,F,G,G,G	VG,G,F,G,G	G,F,G,G,G	G,F,F,G,G
$S_9(O_9)$	G,G,G,VG,G	G,F,F,F,F	G,F,F,F,G	F,F,G,F,G	G,F,G,G,G
$S_{10}(O_{10})$	F,F,F,VG,G	F,F,F,F,F	F,F,P,F,F	F,F,VP,F,P	F,F,F,G,G
$S_{11}(O_{11})$	F,G,G,VG,G	F,F,F,F,F	F,G,F,G,G	G,F,F,G,F	F,F,F,G,G
$S_{12}(C_1)$	VG,VG,VG,VG	G,G,G,G	F,G,G,G	F,F,F,F	F,G,G,G
$S_{13}(C_2)$	VG,VG,VG,VG	G,F,F,F	G,G,G,F	F,F,F,F	F,F,G,G
$S_{14}(C_3)$	G,G,F,G	G,G,G,G	G,G,G,G	F,F,F,F	F,F,F,F
$S_{15}(C_4)$	G,VG,G,F	G,G,G,G	G,G,F,F	G,F,F,F	G,F,F,F

2.3. Evaluation Set of Criteria, DMs and Data

Location criteria for evaluating potential rural districts for rural industrial sites verified reviewing the existing literature and counseling group members of decision makers (DMs). DMs have identified and selected among the prime experts of two relevant burros responsible for rural industries affaires across the study area: the "Rural Industries Burro of Jihad-e-Agriculture Organization" and the "Corporation of Industrial Cities" of the Markazi province. Finally, 11 various geographical, environmental and socio-economical criteria selected to evaluate the potential locations for establishing the rural industrial sites. The five experts of two aforementioned organizations as decision makers have weighted the set of criteria and evaluated the 15 rural districts based on the criteria, using their experience and cognition of the locations, during the May to Jul. 2013. Therefore, the used data for the study objective has been the panel of experts' (DMs) judgements, which linguistically stated by words and represented in Table 3 and Table 4. The list of criteria and the respective linguistic ratings of their weights evaluated by decision makers shown in Table 3. Among these, Criteria C_8 (costs) and C_{11} (environmental impacts) are the cost category criteria (the less the better) while the remaining ones are the benefit category (the more the better) criteria. The linguistic scales and respective fuzzy numbers for criteria weights and rating the rural districts against them also given in Table 1 and Table 2.

2.4. Fuzzy TOPSIS Methodology

Generally, in MCDM contexts it's assumed that $A_1, A_2, \ldots, A_m$ are possible alternatives, $C_1, C_2, \ldots, C_n$ are criteria which measure the performance of alternatives and $\tilde{x}_{ij}$ is the ratings of each alternative A_i with respect to criteria C_j. In fuzzy decision making, each decision maker D_k in a panel of experts assesses these performance ratings qualitatively as $\tilde{R}_k = \tilde{x}_{ijk}$ ($i = 1, 2, \ldots, m$; $j = 1, 2, \ldots, n$; $k = 1, 2, \ldots, K$) which is represented as triangular fuzzy numbers with membership function $\mu_{\tilde{R}_k}(x)$. The adapted and used algorithm of fuzzy TOPSIS methodology in this study is a simple and perfect combination of the following steps, based respectively on the Awasthi et al., 2011 and Gligoric et al., 2010:

Step 1. Aggregation of fuzzy ratings for the criteria and the alternatives.

If the fuzzy rating and importance weight of the kth decision maker are described as TFN $\tilde{R}_k = \tilde{x}_{ijk} = (a_{ijk}, b_{ijk}, c_{ijk})$ and $\tilde{w}_{jk} = (w_{jk1}, w_{jk2}, w_{jk3})$, $i = 1, 2, \ldots, m; j = 1, 2, \ldots, n; k = 1, 2, \ldots, K,$ then the aggregated fuzzy ratings $\tilde{x}_{ij}$ of alternatives with respect to each criteria are given by $\tilde{x}_{ij} = (a_{ij}, b_{ij}, c_{ij}),$ where

$$a_{ij} = \min_k \{a_{ijk}\}, b_{ij} = \frac{1}{K}\sum_{k=1}^{K}\{b_{ijk}\}, c_{ij} = \max_k \{c_{ijk}\}. \quad (2)$$

The aggregated fuzzy criteria weights ($\tilde{w}_j$) of each criterion are also calculated as $\tilde{w}_j = (w_{j1}, w_{j2}, w_{j3})$ where

$$w_{j1} = \min_k \{w_{jk1}\}, w_{j2} = \frac{1}{K}\sum_{k=1}^{K}\{w_{jk2}\}, w_{j3} = \max_k \{w_{jk3}\}. (3)$$

Step 2. Compute the fuzzy decision matrix.

The fuzzy decision matrix $\tilde{D}$ for the alternatives ratings with respect to the criteria and fuzzy weights vector $\tilde{W}$ for the criteria have constructed as follows:

$$\tilde{D} = \left|\tilde{x}_{ij}\right| = \begin{array}{c} \\ A_1 \\ A_2 \\ A_3 \\ \vdots \\ A_m \end{array} \begin{array}{c} \begin{array}{ccccc} C_1 & C_2 & C_3 & \ldots & C_n \end{array} \\ \left|\begin{array}{ccccc} \tilde{x}_{11} & \tilde{x}_{12} & \tilde{x}_{13} & \cdots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{32} & \tilde{x}_{23} & \cdots & \tilde{x}_{2n} \\ \tilde{x}_{31} & \tilde{x}_{12} & \tilde{x}_{33} & \cdots & \tilde{x}_{3n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ \tilde{x}_{m1} & \tilde{x}_{m2} & \tilde{x}_{m3} & \cdots & \tilde{x}_{mn} \end{array}\right| \end{array} \quad (4)$$

$$\tilde{W} = (\tilde{w}_1, \tilde{w}_2, \ldots \tilde{w}_n) \quad (5)$$

Step 3. Construct the normalized fuzzy decision matrix $\tilde{R}$.

The raw data are normalized in order to bring the various criteria scales onto a comparable scale using a linear scale transformation as $\tilde{R} = \left|\tilde{r}_{ij}\right|$, $i = 1, 2, \ldots, m$; $j = 1, 2, \ldots, n$, Each element $\tilde{x}_{ij}$ is transformed using the following equation

$$\tilde{r}_{ij} = \frac{\tilde{x}_{ij}}{\sqrt{\sum_{i=1}^{m}\tilde{x}_{ij}^2}} = \frac{(a_{ij}, b_{ij}, c_{ij})}{\sqrt{\sum_{i=1}^{m}(a_{ij}, b_{ij}, c_{ij})^2}} \; j = 1, 2, \ldots, n. \quad (6)$$

Thus, the normalized decision matrix has given by

$$\tilde{R} = \left|\tilde{r}_{ij}\right| = \left|\begin{array}{ccccc} \tilde{r}_{11} & \tilde{r}_{12} & \tilde{r}_{13} & \cdots & \tilde{r}_{1n} \\ \tilde{r}_{21} & \tilde{r}_{22} & \tilde{r}_{23} & \cdots & \tilde{r}_{2n} \\ \tilde{r}_{31} & \tilde{r}_{32} & \tilde{r}_{33} & \cdots & \tilde{r}_{3n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ \tilde{r}_{m1} & \tilde{r}_{m2} & \tilde{r}_{m3} & \cdots & \tilde{r}_{mn} \end{array}\right| \quad (7)$$

Step 3. Construct the weighted normalized fuzzy decision matrix $\tilde{V}$.

Criteria importance is a reflection of the decision maker's subjective preference as well as the objective characteristics of the criteria themselves (Zeleney, 1982). The weighted normalized matrix $\tilde{V}$ is computed by multiplying the weights $\tilde{V}$ of evaluation criteria with the normalized fuzzy decision matrix $\tilde{R}$:

$$\tilde{V} = \left|\tilde{v}_{ij}\right|, i = 1, 2, \ldots, m; \; j = 1, 2, \ldots, n., \; where \; \tilde{v}_{ij} = \tilde{r}_{ij}(.)\tilde{w}_j \; (8)$$

Ultimately

$$\tilde{V} = \left[\tilde{v}_{ij}\right] = \begin{bmatrix} \tilde{r}_{11}\tilde{w}_1 & \tilde{r}_{12}\tilde{w}_{12} & \cdots & \tilde{r}_{1n}\tilde{w}_n \\ \tilde{r}_{21}\tilde{w}_1 & \tilde{r}_{22}\tilde{w}_2 & \cdots & \tilde{r}_{2n}\tilde{w}_n \\ . & . & \cdots & . \\ \tilde{r}_{i1}\tilde{w}_1 & \tilde{r}_{i2}\tilde{w}_2 & \cdots & \tilde{r}_{in}\tilde{w}_n \\ . & . & . & . \\ \tilde{r}_{m1}\tilde{w}_1 & \tilde{r}_{m2}\tilde{w}_2 & . & \tilde{r}_{mn}\tilde{w}_n \end{bmatrix}. \quad (9)$$

Step 4. Define the ideal and the negative-ideal solutions.

Assuming that $\tilde{A}^+$ identifies the fuzzy ideal solution and $\tilde{A}^-$ the fuzzy negative one, they have defined as follows:

$$\tilde{A}^{+} = \left\{\tilde{v}_1^{+}, \tilde{v}_2^{+}, \ldots, \tilde{v}_n^{+}\right\} = \left\{ \begin{pmatrix} \max_i \tilde{v}_{ij} \mid j \in J \end{pmatrix}, \\ \begin{pmatrix} \min_i \tilde{v}_{ij} \mid j \in J' \end{pmatrix} \right\}, i = 1, 2, \ldots, m \quad (10)$$

$$\tilde{A}^{-} = \left\{\tilde{v}_1^{-}, \tilde{v}_2^{-}, \ldots, \tilde{v}_n^{-}\right\} = \left\{ \begin{pmatrix} \min_i \tilde{v}_{ij} \mid j \in J \end{pmatrix}, \\ \begin{pmatrix} \max_i \tilde{v}_{ij} \mid j \in J' \end{pmatrix} \right\}, \quad (11)$$

$$i = 1, 2, \ldots, m$$

Where, $\max_i \tilde{v}_{ij} = (\max_i v_{ij1}, \max_i v_{ij2}, \max_i v_{ij3})$, $\min_i \tilde{v}_{ij} = (\min_i v_{ij1}, \min_i v_{ij2}, \min_i v_{ij3})$, $J = \{j = 1, 2, \ldots, n \mid j$ associated with the benefit criteria$\}$ and $J' = \{j = 1, 2, \ldots, n \mid j$ associated with the cost criteria$\}$. The benefit and cost criteria are discriminated based on the decision maker desires, which is to maximize or minimize them respectively.

Step 5. Measure the distance of each alternative from ideal and negative-ideal solutions.

The n-Euclidean distance from each weighted alternative $i = 1, 2, \ldots, m$ to the $\tilde{A}^{+}\left(d_i^{+}\right)$ and $\tilde{A}^{-}\left(d_i^{-}\right)$ computed as:

$$\tilde{d}_i^{+} = \sum_{j=1}^{n} \tilde{d}_v(\tilde{v}_{ij}, \tilde{v}_j^{+}) = \left(\sum_{j=1}^{n} (\tilde{v}_{ij} - \tilde{v}_j^{+})^2\right)^{0.5}, i = 1, 2, ..., m \quad (12)$$

$$\tilde{d}_i^{-} = \sum_{j=1}^{n} \tilde{d}_v(\tilde{v}_{ij}, \tilde{v}_j^{-}) = \left(\sum_{j=1}^{n} (\tilde{v}_{ij} - \tilde{v}_j^{-})^2\right)^{0.5}, i = 1, 2, ..., m \quad (13)$$

where $\tilde{d}_v(\tilde{a}, \tilde{b})$ is the distance measurement between two fuzzy numbers $\tilde{a}$ and $\tilde{b}$, which is computed fuzzily suing fuzzy arithmetic operations.

Step 6. Measure of the relative closeness to the ideal solution ($\tilde{CC}_i$) and final ranking of the alternatives.

The fuzzy closeness coefficient of each alternative calculated as:

$$\tilde{CC}_i = \frac{\tilde{d}_i^{-}}{\tilde{d}_i^{-} + \tilde{d}_i^{+}}, i = 1, 2, ..., m \quad (14)$$

The best alternative is the one, which has the shortest distance to the ideal solution. The fuzzy coefficient $\tilde{CC}_i$ represents the distances to the fuzzy positive ideal solution ($\tilde{A}^{+}$) and the fuzzy negative ideal solution ($\tilde{A}^{-}$) simultaneously. Referring to this value, as a FTN, the best alternative is closest to the $\tilde{A}^{+}$ and farthest from the $\tilde{A}^{-}$.

To rank and prioritize alternatives in a decreasing order, the $\tilde{CC}_i$ fuzzy triangular numbers must be defuzzified finally. Defuzzification is the operation in which the value of the output linguistic value inferred by the fuzzy regulations, will translate to a discrete value. There exist several methods to defuzzify and covert a fuzzy number to a crisp value. The centroid or center of gravity as the most commonly used defuzzification method can be expressed as follows (Yager, 1981):

$$\overline{x}_0(\tilde{A}) = \sum_j x_j \mu_{\tilde{A}}(x_j) \Big/ \sum_j \mu_{\tilde{A}}(x_j) \quad (15)$$

where $\overline{x}_0(\tilde{A})$ is the defuzzified value. The defuzzification formula of triangular fuzzy numbers (a, b, c) is (Gligoric et al., 2010):

$$\overline{x}_0(\tilde{A}) = (a + b + c)/3 \quad (16)$$

which is used in this paper.

3. Results and Discussion

First, the aggregated fuzzy weights $\tilde{w}_j$ for each criteria are calculated, based on the fuzzy assessments of 5 decision makers (Table 3) and respective TFNs (Table 1), using Eq. (3). For example, for the criterion C_7 (Security), the aggregated fuzzy weight has given by:

$$\tilde{w}_7 = \left(w_{71}, w_{72}, w_{73}\right) = \begin{pmatrix} \min\{1,3,7,3,5\}, \\ \frac{1}{5}(3+5+9+5+7), \\ \max\{5,7,9,7,9\} \end{pmatrix} = (1, 5.8, 9). \quad (17)$$

Likewise, the aggregate weights for the remaining 10 criteria have computed. Aggregate weights of the 11 criteria have presented in the first row of Table 5. Comparing these fuzzy numbers using Eq. (16) to defuzzify, the highest weight belongs to resources availabilities criteria (C_9) followed by proximities (C_{10}) and infrastructures (C_6). Contrarily the environmental impacts (C_{11}) followed by accessibilities (C_5) are the least weights. As noted by Wang (2012), these weights play an important role in multi-attribute decision models and proper criteria selection is the most important problem in any multi index evaluation system, so that the optimum performance of ranking alternatives depends strictly on measuring adequate relative weights for these criteria (Amiri et al., 2008).

To construct the fuzzy decision matrix $\tilde{D}$, there is need also to aggregate the evaluation ratings given by the experts presented in Table 4. It is noticeable that one of the decision makers did not assess the four candidate sites. The rating linguistic terms transformed to respective positive triangular fuzzy numbers depicted in Table 2. The computation, for example for the industrial rural site $A_1(O_1)$ with respect to the criteria C_3 is, using the Eq.(2) as:

$$\tilde{a}_{13} = (a_{131}, a_{132}, a_{133}) = \begin{pmatrix} \min\{3,1,1,1,3\}, \\ \frac{1}{5}(5+1+1+3+5), \\ \max\{7,3,3,5,7\} \end{pmatrix} = (1, 3, 7). \quad (18)$$

Applying the procedure for all 15 sites with respect to 11 evaluation criteria, the aggregated fuzzy decision matrix $\tilde{D}$ has presented in Table 5.

Table 5. The aggregated weights of criteria ($\tilde{w}_j$) and ratings of rural industrial sites against the criteria ($\tilde{x}_{ij}$)

Ratings	Evaluation criteria										
	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}
Weights	(3, 5, 7)	(5, 8.6, 9)	(7, 9, 9)	(5, 7.4, 9)	(5, 8.2, 9)	(5, 8.6, 9)	(1, 5.8, 9)	(3, 6.2, 9)	(3, 6.2, 9)	(1, 6.2,9)	(3, 7.8, 9)
Sites											
$S_1(O_1)$	(3, 7.0, 9)	(1, 4.6, 9)	(1, 3.0, 7)	(1, 3.4, 7)	(1, 5.0, 9)	(1, 4.2, 7)	(3, 7.0, 9)	(1, 3.4, 7)	(1, 5.0, 9)	(1, 3.4, 7)	(3, 5.8, 9)
$S_2(O_2)$	(3, 7.4, 9)	(3, 4.6, 9)	(1, 6.2, 9)	(3, 6.6, 9)	(3, 5.4, 9)	(1, 5.4, 9)	(3, 7.0, 9)	(3, 6.2, 9)	(1, 5.4, 9)	(1, 4.6, 7)	(3, 6.2, 9)
$S_3(O_3)$	(5, 7.8, 9)	(3, 6.2, 9)	(3, 6.6, 9)	(1, 4.6, 7)	(1, 5.0, 9)	(3, 5.8, 9)	(5, 7.4, 9)	(3, 6.2, 9)	(3, 6.2, 9)	(1, 5.0, 9)	(3, 5.8, 9)
$S_4(O_4)$	(5, 7.8, 9)	(1, 3.8, 7)	(1, 5.4, 9)	(1, 3.0, 7)	(1, 4.6, 7)	(3, 5.8, 9)	(3, 7.0, 9)	(1, 5.0, 9)	(1, 5.0, 9)	(1, 4.2, 7)	(3, 5.8, 9)
$S_5(O_5)$	(5, 7.8, 9)	(3, 7.8, 9)	(1, 4.2, 7)	(3, 7.4, 9)	(3, 5.8, 9)	(3, 5.8, 9)	(5, 7.4, 9)	(3, 5.8, 9)	(3, 5.8, 9)	(3, 5.4, 9)	(3, 6.6, 9)
$S_6(O_6)$	(3, 7.4, 9)	(5, 7.0, 9)	(1, 6.2, 9)	(3, 6.2, 9)	(3, 7.0, 9)	(3, 6.6, 9)	(5, 7.4, 9)	(3, 5.8, 9)	(5, 7.0, 9)	(3, 6.6, 9)	(5, 7.0, 9)
$S_7(O_7)$	(3, 7.4, 9)	(5, 7.8, 9)	(1, 5.0, 9)	(1, 7.0, 9)	(3, 7.8, 9)	(3, 6.6, 9)	(5, 7.4, 9)	(3, 5.8, 9)	(3, 7.4, 9)	(5, 8.6, 9)	(3, 6.6, 9)
$S_8(O_8)$	(3, 7.8, 9)	(3, 7.0, 9)	(1, 6.2, 9)	(1, 5.0, 9)	(1, 5.8, 9)	(3, 7.0, 9)	(5, 7.4, 9)	(3, 6.6, 9)	(3, 7.0, 9)	(3, 6.6, 9)	(3, 6.2, 9)
$S_9(O_9)$	(3, 7.0, 9)	(3, 6.2, 9)	(1, 4.6, 7)	(3, 6.6, 9)	(3, 6.2, 9)	(3, 6.2, 9)	(5, 7.4, 9)	(3, 5.4, 9)	(3, 5.8, 9)	(3, 5.8, 9)	(3, 6.6, 9)
$S_{10}(O_{10})$	(3, 7.4, 9)	(1, 5.0, 9)	(1, 5.4, 9)	(1, 4.6, 9)	(1, 3.8, 7)	(1, 4.6, 9)	(3, 6.2, 9)	(3, 5.0, 7)	(1, 4.6, 7)	(1, 3.8, 7)	(3, 5.8, 9)
$S_{11}(O_{11})$	(3, 7.0, 9)	(3, 5.4, 9)	(1, 5.8, 9)	(1, 3.8, 7)	(3, 6.2, 9)	(3, 5.4, 9)	(3, 7.0, 9)	(3, 5.0, 7)	(3, 6.2, 9)	(3, 5.8, 9)	(3, 5.8, 9)
$S_{12}(C_1)$	(5, 7.5, 9)	(5, 7.5, 9)	(3, 6.5, 9)	(1, 3.5, 7)	(3, 5.5, 9)	(1, 1.0, 3)	(7, 9.0, 9)	(5, 7.0, 9)	(3, 6.5, 9)	(3, 5.0, 7)	(3, 6.5, 9)
$S_{13}(C_2)$	(5, 8.5, 9)	(5, 8.0, 9)	(3, 5.5, 9)	(5, 8.5, 9)	(5, 8.5, 9)	(1, 1.0, 3)	(7, 9.0, 9)	(3, 5.5, 9)	(3, 6.5, 9)	(3, 5.0, 7)	(3, 6.0, 9)
$S_{14}(C_3)$	(7, 9.0, 9)	(5, 8.5, 9)	(3, 6.0, 9)	(3, 6.5, 9)	(3, 5.5, 9)	(3, 6.0, 9)	(3, 6.5, 9)	(5, 7.0, 9)	(5, 7.0, 9)	(3, 5.0, 7)	(3, 5.0, 7)
$S_{15}(C_4)$	(5, 7.0, 9)	(3, 6.5, 9)	(3, 5.0, 7)	(3, 6.5, 9)	(3, 5.5, 9)	(1, 1.0, 3)	(3, 7.0, 9)	(5, 7.0, 9)	(3, 6.0, 9)	(3, 5.5, 9)	(3, 5.5, 9)

Table 6. Weighted normalized fuzzy decision matrix ($\tilde{v}_{ij}$) and ideal solutions.

	C_1	C_2	C_3	C_4	C_5	C_6
$S_1(O_1)$	(.26,1.19,3.83)	(.15, 1.52, 5.86)	(.21, 1.26, 8.49)	(.15, 1.12, 6.75)	(.15, 1.78, 7.69)	(.16, 1.78, 6.75)
$S_2(O_2)$	(.26,1.26,3.83)	(.44, 2.45, 5.86)	(.21, 2.61, 10.9)	(.46, 2.18, 8.68)	(.44, 1.92, 7.69)	(.16, 2.29, 8.68)
$S_3(O_3)$	(.43,1.32,3.83)	(.44, 2.05, 5.86)	(.21, 2.27, 10.9)	(.15, 1.52, 6.75)	(.15, 1.78, 7.69)	(.48, 2.46, 8.68)
$S_4(O_4)$	(.43,1.32,3.83)	(.15, 1.26, 4.56)	(.21, 1.77, 8.49)	(.15, 0.99, 6.75)	(.15, 1.64, 5.98)	(.48, 2.46, 8.68)
$S_5(O_5)$	(.43,1.32,3.83)	(.44, 2.58, 5.86)	(.21, 2.61, 10.9)	(.46, 2.45, 8.68)	(.44, 2.06, 7.69)	(.48, 2.46, 8.68)
$S_6(O_6)$	(.26,1.26,3.83)	(.73, 2.32, 5.86)	(.21, 2.10, 10.9)	(.46, 2.05, 8.68)	(.44, 2.49, 7.69)	(.48, 2.80, 8.68)
$S_7(O_7)$	(.26,1.26,3.83)	(.73, 2.58, 5.86)	(.21, 2.61, 10.9)	(.15, 2.32, 8.68)	(.44, 2.77, 7.69)	(.48, 2.80, 8.68)
$S_8(O_8)$	(.26,1.32,3.83)	(.44, 2.32, 5.86)	(.21, 1.94, 8.49)	(.15, 1.65, 8.68)	(.15, 2.06, 7.69)	(.48, 2.97, 8.68)
$S_9(O_9)$	(.26,1.19,3.83)	(.44, 2.05, 5.86)	(.21, 2.27, 10.9)	(.46, 2.18, 8.68)	(.44, 2.20, 7.69)	(.48, 2.63, 8.68)
$S_{10}(O_{10})$	(.26,1.26,3.83)	(.15, 1.65, 5.86)	(.21, 2.44, 10.9)	(.15, 1.52, 8.68)	(.15, 1.35, 5.98)	(.16, 1.95, 8.68)
$S_{11}(O_{11})$	(.26,1.19,3.83)	(.44, 1.79, 5.86)	(.64, 2.74, 10.9)	(.15, 1.26, 6.75)	(.44, 2.20, 7.69)	(.48, 2.29, 8.68)
$S_{12}(C_1)$	(.43,1.27,3.83)	(.73, 2.48, 5.86)	(.64, 2.32, 10.9)	(.15, 1.16, 6.75)	(.44, 1.96, 7.69)	(.16, 0.42, 2.89)
$S_{13}(C_2)$	(.26,1.44,3.83)	(.73, 2.65, 5.86)	(.64, 2.32, 10.9)	(.77, 2.18, 8.68)	(.74, 3.02, 7.69)	(.16, 0.42, 2.89)
$S_{14}(C_3)$	(.60,1.53,3.83)	(.73, 2.81, 5.86)	(.64, 2.53, 10.9)	(.46, 2.15, 8.68)	(.44, 1.96, 7.69)	(.48, 2.54, 8.68)
$S_{15}(C_4)$	(.43,1.19,3.83)	(.44, 2.15, 5.86)	(.21, 2.10, 8.49)	(.46, 2.15, 8.68)	(.44, 1.96, 7.69)	(.16, 0.42, 2.89)
Fuzzy positive-ideal and negative-ideal solutions						
$\tilde{A}^+$	(.6,1.53,3.83)	(.73,2.81,5.86)	(.64,2.78,10.9)	(.77,2.81,8.68)	(.74,3.02,7.69)	(.48,2.97,8.68)
$\tilde{A}^-$	(.26,1.19,3.83)	(.15,1.26,4.56)	(.21,1.26,8.49)	(.15,0.99,6.75)	(.15,1.35,5.98)	(.16,0.42,2.89)

	C_7	C_8	C_9	C_{10}	C_{11}
$S_1(O_1)$	(.09, 1.42, 4.59)	(.09, .93, 4.88)	(.09, 1.30, 6.97)	(.03, 0.99, 5.98)	(.26, 1.91, 6.59)
$S_2(O_2)$	(.09, 1.42, 4.59)	(.27, 1.69, 6.27)	(.09, 1.41, 6.97)	(.03, 1.34, 5.98)	(.26, 2.05, 6.59)
$S_3(O_3)$	(.14, 1.50, 4.59)	(.27, 1.69, 6.27)	(.26, 1.61, 6.97)	(.03, 1.46, 7.69)	(.26, 1.91, 6.59)
$S_4(O_4)$	(.09, 1.42, 4.59)	(.09, 1.37, 6.27)	(.09, 1.30, 6.97)	(.03, 1.22, 5.98)	(.26, 1.91, 6.59)
$S_5(O_5)$	(.14, 1.50, 4.59)	(.27, 1.59, 6.27)	(.26, 1.51, 6.97)	(.10, 1.57, 7.69)	(.26, 2.18, 6.59)
$S_6(O_6)$	(.14, 1.50, 4.59)	(.27, 1.59, 6.27)	(.44, 1.82, 6.97)	(.10, 1.92, 7.69)	(.44, 2.31, 6.59)
$S_7(O_7)$	(.14, 1.50, 4.59)	(.27, 1.59, 6.27)	(.26, 1.93, 6.97)	(.16, 2.51, 7.69)	(.26, 2.18, 6.59)
$S_8(O_8)$	(.14, 1.50, 4.59)	(.27, 1.80, 6.27)	(.26, 1.82, 6.97)	(.10, 1.92, 7.69)	(.26, 2.05, 6.59)
$S_9(O_9)$	(.14, 1.50, 4.59)	(.27, 1.48, 6.27)	(.26, 1.51, 6.97)	(.10, 1.69, 7.69)	(.26, 2.18, 6.59)
$S_{10}(O_{10})$	(.09, 1.26, 4.59)	(.27, 1.37, 4.88)	(.09, 1.20, 5.42)	(.03, 1.11, 5.98)	(.26, 1.91, 6.59)
$S_{11}(O_{11})$	(.09, 1.42, 4.59)	(.27, 1.37, 4.88)	(.26, 1.61, 6.97)	(.10, 1.69, 7.69)	(.26, 1.91, 6.59)
$S_{12}(C_1)$	(.20, 1.83, 4.59)	(.45, 1.91, 6.27)	(.26, 1.69, 6.97)	(.10, 1.46, 5.98)	(.26, 2.15, 6.59)
$S_{13}(C_2)$	(.20, 1.83, 4.59)	(.27, 1.50, 6.27)	(.26, 1.69, 6.97)	(.10, 1.46, 5.98)	(.26, 1.98, 6.59)
$S_{14}(C_3)$	(.09, 1.32, 4.59)	(.45, 1.91, 6.27)	(.44, 1.82, 6.97)	(.10, 1.46, 5.98)	(.26, 1.65, 5.13)
$S_{15}(C_4)$	(.09, 1.42, 4.59)	(.45, 1.91, 6.27)	(.26, 1.56, 6.97)	(.10, 1. 6, 7.69)	(.26, 1.82, 6.59)
Fuzzy positive-ideal and negative-ideal solutions					
$\tilde{A}^+$	(.2,1.83,4.59)	(.09,0.93,4.88)	(.44,1.93,6.97)	(.16,2.51,7.69)	(.26,1.65,5.13)
$\tilde{A}^-$	(.09,1.26,4.59)	(.45,1.91,6.27)	(.09,1.2,5.42)	(.03,0.99,5.98)	(.44,2.31,6.59)

In the next step, the normalization of the fuzzy decision matrix of industrial sites was performed using Eq. (6) and in following the obtained normalized fuzzy decision matrix ($\tilde{R}$) multiplied by the criteria weights diagonal matrix ($\tilde{W}$) in order to compute the weighted fuzzy decision matrix ($\tilde{V}$). To illustrate the procedure, the normalized rating for site $A_1(O_1)$ with respect to the criteria C_3 (water resources availability) is given by:

$$\tilde{r}_{13} = \frac{(1,3,7)}{\left((1,3,7)^2 + \ldots + (3,5,7)^2\right)^{0.5}} = \frac{(1,3,7)}{(7.42,21.4,33)} \quad (19)$$
$$= (\frac{1}{33}, \frac{3}{21.4}, \frac{7}{7.42}) = (0.03, 0.14, 0.94)$$

and the respective weighted rating is also calculated as:

$$\tilde{v}_{13} = \tilde{r}_{13}.\tilde{w}_3 = (0.03, 0.14, 0.94)(.)(7,9,9)$$
$$= (0.21, 1.26, 8.49). \quad (20)$$

Likewise, the normalized and weighted normalized values of the sites for the remaining criteria have computed. Ignoring the normalized matrix ($\tilde{r}_{ij}$), the weighted normalized matrix of fuzzy ratings ($\tilde{v}_{ij}$) is denoted in Table 6.

The next step is to identify and compute of the fuzzy positive-ideal solution and the fuzzy negative-ideal solutions using Eqs. (10)-(11) for the rural industrial sites. For example the $\tilde{A}^+$ and $\tilde{A}^-$ solutions for criteria C_3 are $\tilde{A}^+ = (0.64, 2.78, 10.9)$ and $\tilde{A}^- = (0.21, 1.26, 8.49)$ respectively. Similarly, the computations performed for all of the criteria and results have presented in the last two rows of the same Table 6.

Applying the Eqs. (12)-(13) at the following, the fuzzy distances of each of the industrial sites from the positive- and negative-ideal points ($\tilde{d}_i^+$ and $\tilde{d}_i^-$) were measured. For example, the distance of site S_1 from the point $\tilde{A}^+$ is, based on the Table 6, computed as:

$$\tilde{d}_i^+ = \begin{Bmatrix} ((.26,1.19,3.83) - (.6,1.91,3.83))^2 + \ldots \\ + ((.26,1.91,6.59) - (.26,1.65,5.13))^2 \end{Bmatrix}^{0.5} \quad (21)$$
$$= (23.1, 3.58, 19.5).$$

According to these measures, the relative fuzzy closeness coefficients $\tilde{CC}_i$ of the sites have also computed using Eq. (14). For the S_1, the fuzzy closeness coefficient for example is as:

$$\tilde{CC}_1 = \frac{(18.7, 1.81, 20.5)}{(18.7, 1.81, 20.5) + (23.1, 3.58, 19.5)} \quad (22)$$
$$= (0.47, 0.34, 0.49).$$

Table 7. Measures of fuzzy distances and relative closeness of the sites to the positive- and negative-ideal solutions.

Sites	d_i^+	d_i^-	$\tilde{CC}_i$	Defuzzification
$S_1(O_1)$	(23.1, 3.58, 19.5)	(18.7, 1.81, 20.5)	(0.47, 0.34, 0.49)	0.431
$S_2(O_2)$	(22.8, 2.20, 22.2)	(18.3, 2.96, 23.2)	(0.40, 0.57, 0.56)	0.513
$S_3(O_3)$	(22.6, 2.46, 22.2)	(18.2, 2.86, 23.0)	(0.40, 0.54, 0.56)	0.502
$S_4(O_4)$	(23.0, 3.27, 20.9)	(18.6, 2.41, 21.7)	(0.44, 0.42, 0.52)	0.461
$S_5(O_5)$	(22.6, 2.07, 21.8)	(18.2, 3.07, 22.7)	(0.41, 0.60, 0.56)	0.521
$S_6(O_6)$	(22.5, 1.60, 22.8)	(18.0, 3.52, 23.7)	(0.39, 0.69, 0.58)	0.554
$S_7(O_7)$	(22.6, 1.32, 22.8)	(18.2, 3.86, 23.7)	(0.39, 0.75, 0.58)	0.572
$S_8(O_8)$	(22.8, 1.99, 22.8)	(18.4, 3.43, 23.7)	(0.40, 0.63, 0.57)	0.535
$S_9(O_9)$	(22.6, 2.03, 21.8)	(18.2, 2.99, 22.7)	(0.41, 0.60, 0.56)	0.520
$S_{10}(O_{10})$	(23.1, 3.20, 21.0)	(18.6, 2.06, 21.9)	(0.43, 0.39, 0.53)	0.450
$S_{11}(O_{11})$	(22.7, 2.45, 21.8)	(18.3, 2.66, 22.7)	(0.41, 0.52, 0.55)	0.495
$S_{12}(C_1)$	(22.5, 3.59, 20.2)	(18.0, 2.21, 21.0)	(0.44, 0.38, 0.52)	0.446
$S_{13}(C_2)$	(22.2, 2.88, 20.8)	(17.8, 3.20, 21.7)	(0.42, 0.53, 0.54)	0.496
$S_{14}(C_3)$	(22.2, 2.04, 21.9)	(17.8, 3.37, 22.8)	(0.40, 0.62, 0.57)	0.531
$S_{15}(C_4)$	(22.5, 3.34, 20.3)	(18.0, 2.00, 21.2)	(0.43, 0.37, 0.52)	0.444

Table 8. Final ranking of rural industrial sites

Rural industrial sites	$\tilde{x}_0(\tilde{CC}_i)$	Final ranking
$S_7(O_7)$	0.572	1
$S_6(O_6)$	0.554	2
$S_8(O_8)$	0.535	3
$S_{14}(C_3)$	0.531	4
$S_5(O_5)$	0.521	5
$S_9(O_9)$	0.520	6
$S_2(O_2)$	0.513	7
$S_3(O_3)$	0.502	8
$S_{13}(C_2)$	0.496	9
$S_{11}(O_{11})$	0.495	10
$S_4(O_4)$	0.461	11
$S_{10}(O_{10})$	0.450	12
$S_{12}(C_1)$	0.446	13
$S_{15}(C_4)$	0.444	14
$S_1(O_1)$	0.431	15

Table 7 shows the results of the fuzzy distances and closeness coefficients computations for all of the rural industrial sites. The closeness fuzzy coefficients were finally defuzzified using the Eq. (16) in order to prioritize the sites. The defuzzified values and final ranking order of the 15 rural industrial sites has presented in Table 8.

Obviously, the best locations for the rural industrial sites in the study area are the points S_7 (O_7), S_6 (O_6), S_8 (O_8) and S_{14} (C_3), which 3 first of them are now on operation. Contrarily, the last orders belong to the points S_1 (O_1), S_{15} (C_4), S_{12} (C_1) and S_{10} (O_{10}). Accordingly, although two cases of the last orders (14 and 13) belong to the candidate sites (S_{15} and S_{12}), but the worst order (15),representing the worst location to establish a rural industrial site, is also an operant site (S_1).

4. Conclusion

The contribution of rural industrialization in rural development policies is not only unavoidable, but the role of such procedures and operations is very crucial in success of the rural development and poverty alleviation projects, especially in developing countries. In addition to the type and scale, the locational or spatial situations is one of the most important and effective prerequisites for rural industries to meet the success. This paper presents a multi-criteria decision making framework for location planning for rural industrial sites under a fuzzy environment. The studied locations for implementing rural industrial sites are 11 operant and four candidate sites as well. The evaluation set of criteria are also various geographical, environmental, social and economical attributes containing climatic and geomorphologic situations, water, labor and raw material resources availability, accessibilities, infrastructures, security, costs, proximities, expansion possibility and environmental impacts. Due to the uncertainty and imprecision inherently involved in assessing such criteria and further more rating the alternatives against them, the decision problem studied quantitatively using fuzzy multi-criteria TOPSIS methodology. The final results as closeness coefficients of the industrial sites to the ideal assumptive solution determined fuzzily and the rankings of the locations obtained via the defuzzification of the coefficients. Results revealed some inappropriateness of site selection and location allocations to industrialize the rural study. Finally, the strength of the study is the ability to deal with multiple criteria and model uncertainty in location planning for rural industrialization through linguistic parameters and fuzzy theory.

References

[1] Alvarez, S.A., Barney, J.B. and Newman, A.M.B., 2015. The poverty problem and the industrialization solution. Asia Pacific Journal of Management 32:23-37.

[2] Amiri, M., Zandieh, M., Vahdani, B., Yazdani, M. and Soltani, R., 2008. A hybrid MCDM model with interval weights and data for convention site selection. Journal of Applied Sciences 8 (15): 2678-2686.

[3] Awasthi, A., Chauhan, S.S., Goyal, S.K., 2011. A multi-criteria decision making approach for location planning for urban distribution centers under uncertainty. Mathematical and Computer Modelling 53: 98-109.

[4] Bojadziev, G., and Bojadziev, M., 1998. Fuzzy sets and fuzzy logic applications. Singapore: World Scientific.

[5] Bruton, G.D., Khavul, S., and Chavez, H., 2011. Microfinance in emerging markets: Building a new line ofinquiry from the ground up. Journal of International Business Studies, 42: 718-739.

[6] Chamodrakas, I., Alexopoulou, N., Martakos, D., 2009. Customer evaluation for order acceptance using a novel class of fuzzy methods based on TOPSIS. Expert Systems with Applications 36: 7409-7415.

[7] Chen, C.T., 2000. Extension of the TOPSIS for group decision making under fuzzy environment. Fuzzy Sets and Systems 114: 1-9.

[8] Chen, C.T., 2001. A fuzzy approach to select the location of the distribution center. Fuzzy Sets and Systems 118: 65-73.

[9] Chu, T.C., 2002. Selecting plant location via a fuzzy TOPSIS approach. The International Journal of Advanced Manufacturing Technology 20: 859-864.

[10] Corral, L. and Reardon, T., 2001. Rural nonfarm income in Nicaragua. World Development 29 (3): 427-442.

[11] Ekmekcioglu, M., Kaya, T., Kahraman, C., 2010. Fuzzy multi-criteria disposal method and site selection for municipal solid waste. Waste Management 30:1729-1736.

[12] Epstein, T.S. and Jezeph, D., 2001. Development - there is another way: a rural-urban partnership development paradigm. World Development 29 (8): 1443-1454.

[13] Gharanejad, H., 1993. An introduction to the industrial geography. University of Isfahan, Isfahan, Iran.

[14] Gligoric, Z., Beljic, C. and Simeunovic, V., 2010. Shaft location selection at deep multiple orebody deposit by using fuzzy TOPSIS method and network optimization. Expert Systems with Applications 37: 1408-1418.

[15] Hwang, C.L., and Yoon, K., 1981. Multiple attribute decision making: Methods and applications. Berlin: Springer.

[16] Kaufmann, A. and Gupta, M.M., 1985. Introduction to fuzzy arithmetic: Theory and applications. New York: Van Nostrand Reinhold.

[17] Khadka, R.B. and Shrestha, U.S., 2011. Process and procedure of environmental impact assessment application in some countries of South Asia: are view study. Journal of Environmental Science and Technology 4 (3): 215-233.

[18] Kuo, M.-S., Tzeng, G.-H., Huang, W.-C., 2007. Group decision-making based on concepts of ideal and anti-ideal points in a fuzzy environment. Mathematical and Computer Modelling 45: 324–339.

[19] Li, D.F., 2007. A fuzzy closeness approach to fuzzy multi-attribute decision making. Fuzzy Optimization and Decision Making 6 (3): 237-254.

[20] Lin, H.T. and Chang, W.L., 2008. Order Selection and pricing methods using flexible quantity and fuzzy approach for buyer evaluation. European Journal of Operational Research 187 (2): 415-428.

[21] Liu, Y., Wang, G. and Zhang, F., 2013. Spatio-temporal dynamic patterns of rural area development in eastern coastal China. Chinese Geographical Science 23(2): 173-181.

[22] Markazi Office of Government General. 2009. Statistical handbook of Markazi province. Planning dept. of Office of Government General, Arak, Iran.

[23] Mei, Z., 1993. Non – agricultural industrial development in Chinese rural areas. Development Policy – Review 11: 383-392.

[24] Mukherjee, A. and Zhang, X., 2007. Rural industrialization in China and India: role of policies and institutions. World Development 35 (10): 1621-1634.

[25] North, D. and Smallbone, D., 1996. Small business development in remote rural areas: The example of mature manufacturing firms in Northern England. Journal of Rural Studies 12 (2):151-167.

[26] Prahalad, C.K., 2006. The fortune at the bottom of the pyramid. Upper Saddle River: Pearson Education.

[27] Sachs, J., 2005. The end of poverty. New York: Penguin.

[28] Sharifonnasabi, M., 1986. The contribution of the industrialization in rural development plannings in Iran. Ministry of Jihad-e-Agriculture, Tehran, Iran.

[29] Sharma, D.K., D. Ghosh & J.A. Alade. 2006. A fuzzy goal programming approach for regional rural development planning. Applied Mathematics and Computation 176: 141-149.

[30] Shen, X., 1999. Spatial inequality of rural industrial development in China, 1989–1994. Journal of Rural Studies15 (2): 179-199.

[31] Simmons, C. and Supri, S., 1997. Rural development, employment and off-farm activities: A study of rural households in Rurka Kalan development block, North-west India. Journal of Rural Studies13 (3): 305-318.

[32] Song, H., Thisse, J-F. and Zhu, X., 2012. Urbanization and/or rural industrialization in China, Regional Science and Urban Economics 42: 126-134.

[33] Tambunan, T., 1995. Forces behind the growth of rural industries in developing countries. A survey of literature and a case study from Indonesia. Journal of Rural Studies 11 (2): 203-215.

[34] Tesfayohannes, M. and Temtime, Z.T., 2002. Problems and prospects of technology transfer in developing economies: a review. Journal of Applied Sciences 2 (3): 332-338.

[35] Thangamuthu, C., 1992. Approaches to rural industrialization: a perspective. Bharathidason University, India.

[36] Yager, R.R., 1981. A procedure for ordering fuzzy subsets of the unit interval. Information Sciences 24: 143-161.

[37] Yang, T. and Hung, C.C., 2007. Multiple-attribute decision making methods for plant layout design problem. Robotics and Computer-Integrated Manufacturing 23: 126-137.

[38] Yildirim, T.B. and Yilmaz, R., 2005. High performance plant selection for landscape reclamation in the subtropic climate zone: a case study. Journal of Agronomy 4: 262-266.

[39] Yong, D., 2006. Plant location selection based on fuzzy TOPSIS. International Journal of Advanced Manufacturing Technology 28: 839-844.

[40] Wang, S., 2012. A novel multi-attribute allocation method based on entropy principle. Journal of Software Engineering.

[41] Zadeh, L.A., 1965. Fuzzy sets. Information and Control 8: 338-353.
[42] Zadeh, L.A., 1975. The concept of a linguistic variable and its application to reasoning – I. Information Science 8: 199-249.
[43] Zeleney, M., 1982. Multiple criteria decision making. New York: McGraw Hill.
[44] Zimmermann, H.J., 1992. Fuzzy set theory and its applications. Boston: Kluwer.