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The Application of Fuzzy Multi-attribute Group Decision Making to Prioritize the Landscapes with high Ecological value: Khoshk River in Shiraz

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ABSTRACT: The expansion of major cities regardless of the scientific planning principles has led to the emergence of negative urban development impacts in Iran such as the degradation of natural resources and various forms of pollution. Undoubtedly, urban rivers can enhance the ecological value of the earth to an optimal extent. However, to benefit from these potentials, appropriate planning looks inevitable. Due to the lack of data and information, analyzing the quality of these resources requires the application of new methods which consider the uncertainties and complexities of the issue in the decision making. This research presents an application of fuzzy TOPSIS multi attribute group decision making to identify factors causing land degradation, distinguish the most optimal areas based on their ecological values and provide suggestions on landscape improvement. To this end, the development of Shiraz city along the Khoshk River corridor was investigated using the 1:25000 maps and satellite images (ICONOS). With respect to the river attributes and adjacent lands, the riverside was divided into four heterogeneous zones. Then, to distinguish the most optimal zone based on the ecological values, the fuzzy decision making method was applied. To this end, the expansion of human activities and biophysical criteria were defined, separately. A number of experts determined the importance of each indicator qualitatively. Finally, using the group decision making theory and fuzzy TOPSIS technique, the researchers identified the most suitable zone based on the "biophysical criteria" and "human activity criteria" separately as well as the whole criteria, and provided suggestions on the landscape improvement.

Key words: Landscape ecology, Decision making, Fuzzy method, TOPSIS, Criteria, Riverside

INTRODUCTION

Rivers flow not only in place but also in time, they are moving elements and their flows make them restore continuously. Urban rivers as the natural part of cities have important roles in the formation and expansion of cities and act as the basic context of old gardens, clean air corridors, refuge of birds (Nejadi *et al.,* 2012; Fumagalli and Toccolini, 2012; Faizi *et al.,* 2012; Kanokporn and Iamaram, 2011; Seifollahi and Faryadi, 2011) . Most importantly (Above all), they mesh the urban life with the nature. But these natural structures in urban areas are degrading as a result of the urban developments and the ignorance of their vital values (Yavari, 2003; Pirani and Secondi, 2011; Jing and Zhiyuan, 2011; Ahmed *et al.,* 2011; Spanou *et al.,* 2012; Feng *et al.,* 2012;Odindi and Mhangara, 2012Basso *et al.,* 2012; Rasouli *et al.,* 2012). The spreading of cities to the riversides causes changes to the nature of these ecosystems. In cities; the natural landscape and valuable ecological elements (rivers corridors) are now constantly and hectically changing to the condensed spaces and transportation roads (Baschak and Brown, 1998). While this functional approach has negative impacts on natural values of rivers, it is assumed that the quality of urban environment can be improved towards sustainability of the city through conserving and restoring of the structural elements of urban landscape and creating proper correlation and connectivity among these (Farina 2006) (Forman, 1995) (Masnavi, 2007).Development should not be considered as an imposition to the environment. Meanwhile the nature and the landscape should be considered as the context and matrix of urban development (Newman, 1999). The urban and industrial developments have disturbed the regularity of the nature sand the natural areas like rivers, wetlands and grasslands which were previously sustainable and balanced systems (Taghvayi and Sarayi, 2003). By degrading these natural patches and corridors, the connection between near ecosystems has been cut gradually and it has led to the instability and lack of sustainability (Hanski, 1999). The urban rivers

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corridors can preserve and even enhance the ecological value of the earth (Opdam, 2006). However for preservation and utilization of these areas planning is essential. Rivers are the most important structural elements in arid plain and mountain foot areas which provide the optimal/desirable situation/areas in respect of environment, culture and urban aesthetic for civil society (Yavari, 2003)(Pasban hazrat, 2002). Although rivers as individual and distinct elements linearly usually pass through the cities, they face different kinds of conditions which create special characteristics in them and this case emphasizes on the special designing and planning each point of the city. The urban ecology is the preliminary condition for cities in providing appropriate environment for citizens (Trragao and Ngel, 2006).However, the awkward growth of cities dilutes the role of nature and its natural elements in our big cities.Consequently, at present the lack of natural elements and the citizens' deprivation of attractions and advantages of nature have become the main problems of contemporary urbanity (Dieleman and Wegener, 2004). The thought-provoking fact is that the creation of new green spaces at an extensive level is very expensive and will face restrictions due to the excessive cost of urban lands and the lack of water resources. Therefore, it is essential to employ the existing natural potentials of cities in order to reach the sustainability in cities and to preserve remnant natural systems, enhance the connectivity among green patches, and renovate natural corridors of rivers by fundamental planning. In addition, some rivers flow through the center or edge of urban context and are of great importance due to their environmental effects as the sources of creating ecological connectivity and land sustainability in addition to their positive effects on surrounding climate quality and the aesthetics of landscape (Makhzoumiand Pungetti, 1999)(Messerli, 1983). In the environmental sciences, we face complex natural or artificial ecosystems, various factors influencing the quality of environment, and the lack of exact and trustworthy data. As a result, the need for the methods which can model the real world and help change the qualitative data into the quantitative data for the decision making purposes, looks essential (Guy and Marvin, 2000) (Creswell, 1994). The fuzzy theory is determined as a method for using these kinds of qualitative information (Li, 2003). The fuzzy logic is the best means for modeling on complicated systems, and those which no adequate data are available about them or the existing data are ambiguous and inexplicit (Chen, 2009). Decision makers (experts) determine the importance of indicators and the amount of options in each criterion using linguistic variables (Deng-Feng, 2007; Zimmermann, 1991). Linguistic variable is a variable whose values are linguistic terms (Ching-hsue and Lin， 2002). The concept of linguistic variable is very useful in situations where decision problems are too complex or too ill-defined to be described properly using conventional quantitative expressions.

MATERIALS & METHODS

The following items have been applied in the research:

- Maps of the National Geographical Organization: scale 1:25000
- The GIS map of Shiraz municipality: scale 1:25000, 2010
- Satellite images Iconos, Satellite images IRS, Iranian space agency, 2010
- Study of reports and utilizing information and background researches on Khoshk River in previous years,
- Study of proposals and under performance projects related to the river by municipality and consultant engineers,
- Field study, site data collection, updating the existing maps,
- Providing pictures and videos,

The rest of maps related to recognition and analyses of the site have been provided with the use of above-mentioned items and have been used in order to investigate parameters to compare and evaluate the area. Further, with respect to the recognition and study of site condition, the required information was extracted from maps and field studies. Zoning was performed based on the acquired information which resulted in the distinction of 4 Zones in Shiraz (kokabi, 2006) (yavari, 2003) (yavari *et al.*, 2007).

The information was analyzed via comparison method of four existing Zones (Kokabi & Aminzade, 2009)and the ideas of 3 experts (decision makers) on the base of 1) "biophysical" and "human activity" criteria, 2) ecological characteristics of landscape, 3) patch size, 4) homogeneity in structure and 5) patch heterogeneity in each Zone. Opinions have been as linguistic variables for exploring the importance of each criteria and ecological value of zones. Then, they have been converted to the positive trapezoidal Fuzzy numbers. Through Fuzzy TOPSIS Method (Technique for Order Preference by Similarity to Ideal Solution) and the group decision making, the zone which has the most ecological ability has been selected. Two main types of aridity have been distinguished (Tricart, 1991). One is due to the global climatic regimes while the other (such as Shiraz city case) "non-regional" aridity is caused by local geographic barriers (Fig.1). Iran is located on the warm-arid climatic zone and is affected by drought for many years; also the water level of rivers and lakes tends to decrease continuously (Yavari *et al.*, 2007). For years, the Iranian have chosen their residences and built cities in areas/regions where they can utilize the water from higher areas and existing valleys (CHI, 1968). Based on this idea, more than 200 cities in the country have been built beside mountains foot and along the valleys derived from them (Pasban Hazrat, 2002) (Darvish zadeh, 1990).

The Khoshk River located in Shiraz City has been selected as a case study. This seasonal river with a flood regime stretches from the northwest toward the southeast of Shiraz city and passes through different parts of the city. Its source is Ghalat Mountains which is located 26 km to the northwest of the city. The river is a part of Shiraz- Neiriz watershed and one of the streams of Maharloo sub-watershed (Monavari, 2001) (Fig.2). The minimum altitude in its watershed is 1470m (surface of the Maharloo Lake) and its maximum altitude is 2995m from the sea level (Crest of Ghalat Mountain) (Fig.3). Being located in drainage line of the city, it eventually receives all surface water and streams of different parts of the plain. After passing through different parts of city (Afshin, 1995), this river comes out of the city without any considerable utilization of its natural potentials and finally joins the Maharloo Lake (Kokabi, 2006). Developments of Shiraz around the river, and the development projects and interference in its watershed have had a remarkable role in changes of steeps and accordingly morphologic characters and volume of water and floods. Regarding the flood regime of the Khoshk River, its reaction which is influenced by natural and unnatural factors is unsustainable in different areas.

The urban part of the river which passes through the different structures of the city (Fig.4, Fig.5) begins from the joining point of southern division of Golestan River and the main river. It contains two divisions, Nahr-Azam and Chenar-Soukhte which join to each other at the beginning of the Chamran Boulevard and form "Khoshk River" that passes through the drainage line of the plain (Fig.6). It continues with bridges of Hoseyn Abad, Motahari, Pirnia towards the upstream of Sharifabad Bridge (Fig.3). The steep of this zone is various due to the building of different constructions such as building of walls, bridges, sidewalks and organization of routs. The length of this area (urban part) is about 8.5 km (report of HCE, 2004) and the subdivisions of Darvazeh Quran, Sadi and Bajgah join to the Khoshk River along this part.

After the analysis of obtained data and investigation of different sites, 4 major zones were identified in the city (Fig.7):

1. The city entrance (suburb) and plants' zone
2. New development and gardens zone
3. City center and old town zone,
4. Industry, suburb and city exit zone

Each of these zones has characteristics which are discussed in the next part.

Zone 1- The city entrance (suburb) and plants' zone (Fig.7): Building of wall has not been carried on in most

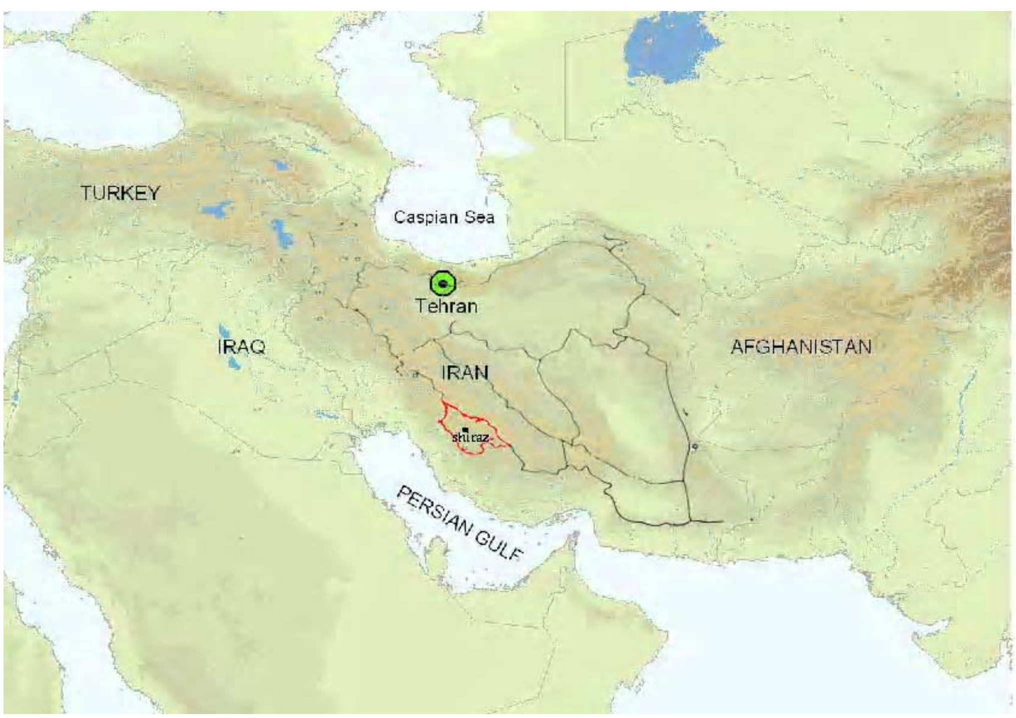

Fig. 1. Shiraz in the context of arid plateau of Iran. Its "non-regional aridity" is caused by local geographic barriers (Darvish zadeh, 1990)

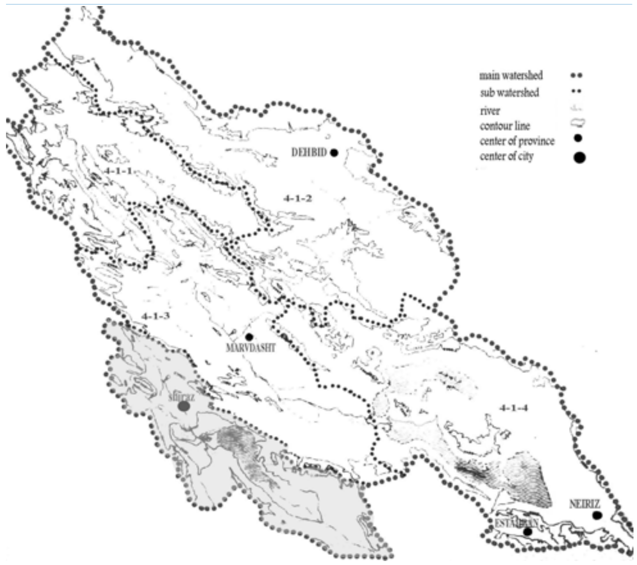

Fig. 2. Rivers and sub watersheds of Shiraz-Neiriz watershed (Afshin, 1995). Maharloo sub watershed and Shiraz city are in the south west of map

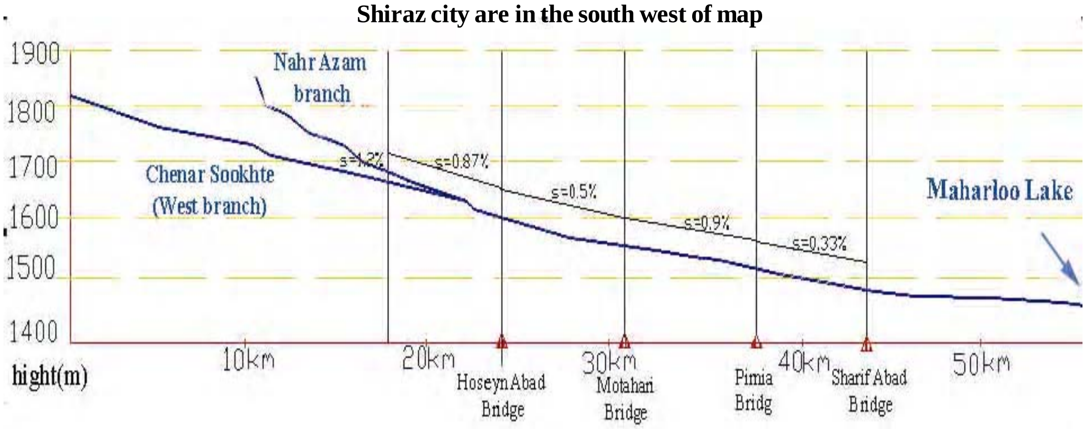

Fig. 3. The longitudinal section of the river passing through the city. In this Fig. existing bridges are seen. The total length of the river is 62 km and according to the report of Haseb Counseling Engineers (2004), the slope of river is changing between 0.33and 1.2%

parts around the river. The river has its natural condition mostly and bed of the river is covered by a thick layer of stone. The zone has a natural potential and some parts of that are predicted for recreation. In this zone the landscape is heterogynous and is composed of a series of Single-unit residential, open and green patches, gardens, factories, industrial area and other land uses. The main problem in this zone is the penetration of construction patch in open and natural patches. In some parts construction is extended to the margin of the river which is not only an obstacle for passing of the flow but also it increases the hazard of the flood because of its location in upstream (Messerli, 1983).

Zone 2- New development and gardens zone (Fig.7): The body and margin of the river is semi natural. A stony wall is built on margin of the river. In the first part of this zone the context of surroundings is more natural and has more gardens and in the downstream of the river the urban constructions and buildings gradually penetrates to the river margin. In general, the density of green space and gardens is high and the natural form of rivers has mostly remained. During past years, the green patches of this zone are gradually decreased due to the increase in land cost, dividing of gardens to small parts, land use changes, the private ownership of the gardens and the increase of constructions. At the beginning of this zone, gardens can be seen on both sides of two divisions of the river and the flow is more in this zone because of connection of Azam stream (which is permanent) to the main river and also the existence of Qantas. The context of this zone is heterogynous. The grain size is large to medium

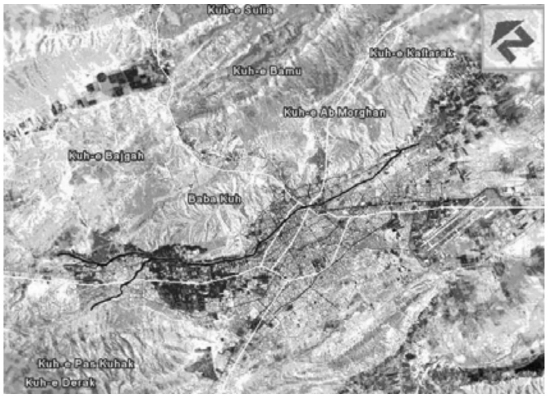

Fig. 4. Shiraz Satellite image, Khoshk River, surrounding mountains and main access roads are seen

Fig. 5. Shiraz plain in a closed watershed (Shiraz-Neiriz watershed) ending to the salt lake (Maharloo)

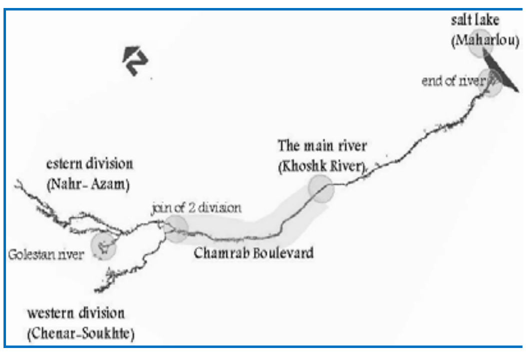

Fig. 6. Plan of two divisions of Khoshk river (eastern division: Nahr- Azam and western division: Chenar-Soukhte) and the rest of this river to the Maharloo Lake (The author, a)

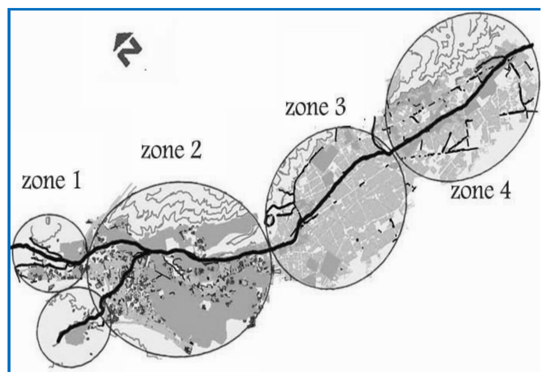

Fig.7. Shiraz city including four distinct zones

in downstream and land use is different including: gardens, residential, institutional, commercial and etc. The grain size is large due to vastness of gardens and green spaces in this zone. The main problems are decreasing of gardens and green patches and also road construction on both sides of the river.

Zone 3- city center and old town zone (Fig.7): Regarding the old town in this zone and its concentrated and irregular form with narrow alleys and also historical and valuable constructions, the riverside is very narrow. The river has the most interference with the city and mostly the view of the river is restricted because of the height of the walls around it. This zone is completely concentrated and in many parts the construction has been extended to the edge of the river. The parallel road to the river has been constructed in both sides of the river. Unfortunately, pollutants, household, industrial and clinical wastes enter to the river. In recent years some of the manufactures have undertaken sewage treatment before discharging it to the river. This zone is flooding area and is threaten by flood hazard. The number of bridges is more and their distances are less in this part. The wall around the river margin has become a wide and deep canal in which water passes. The context of this zone is homogeneous and its grain size is small. Land use is residential, residential-commercial, educational and institutional. The density of green patches (orchard, farmland and suburban) has been decreased and there are only some royal gardens, old bungalows and parks far from the river. The main problem of this zone is flooding due to the limited space around the river. In fact, access to the river is difficult because of wall existence on both sides.

Zone 4- Industry, suburb and city exit zone (Fig.7).The pollution percentage is considerable in this zone. This pollution enters the river through drainage and large diameter tubes from surroundings and the upstream land. In the older maps, farms are seen in margin of the river which has been mostly converted to highways and dense building concentrations currently.

In this zone the river wall is gradually disappeared and converted to natural river margin. The main problem is pollution of water and soil and entering of wastes to the river. The River has its natural morphological form but it is highly polluted. In certain parts, it is impossible to see the river because the distance of roads from the river. The density of construction has been decreased. Land use in this zone is for factory, farm lands around the river, open spaces, routs of linier planted trees, urban services, industry, residential units and under construction buildings. This zone is heterogeneous and the grain size is small to medium.

In the next phase, the 4 distinguished zones were investigated in respect of natural condition, landscape structure, grain size, structural homogeneity and other ecological attributes. Then the group decision making theory in fuzzy environment was applied. The investigation procedures and results will be presented in consequent parts of paper (kokabi, 2006) (kokabi & Aminzade, 2009).

Seven linguistic variables were used for importance of qualitative value of each criterion in this article. Also, values of each alternative on each criterion are used as it is shown in Table1. The linguistic variables are stated through the positive trapezoidal Fuzzy numbers which its membership factors are clear. Options include 4 parts or zones. (n=4): zone1, zone2, zone3, and zone4. These zones are prioritized with regard to their conditions and the set criteria. The criteria are divided into two groups. The first group includes "human activities criteria" encompassing a) the dominant use of land and adjacent lands, b) structural heterogeneity and homogeneity, c) accessibility and d) disturbing indicators (Table 2). The second group is "biophysical criteria" including a) the condition of green and open patch, b) natural corridor, river and c) water and soil resources (Table 3).

Supposing the value of alternative $F = \{f_1, f_2, ..., f_n\}$ on the criterion $X = \{x_1, x_2, ..., x_m\}$ given by decision maker $p_k (k = 1,2,..., K)$ is $\tilde{f}_{ij}^k = (a_{ij}^k, b_{ij}^k, c_{ij}^k, d_{ij}^k)$. Hence, a FMAGDM (Fuzzy Multi Attribute Group Decision Making) problem can be concisely expressed in the matrix format as follows:

$$k = 1,2,..., K$$

$$\tilde{Y}^k = (\tilde{f}^k_{ij})_{m\times n} = \begin{bmatrix} \tilde{f}^k_{11} & \tilde{f}^k_{12} & \ldots & \tilde{f}^k_{1n} \\ \tilde{f}^k_{21} & \tilde{f}^k_{22} & \ldots & \tilde{f}^k_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ \tilde{f}^k_{n1} & \tilde{f}^k_{n2} & \ldots & \tilde{f}^k_{nm} \end{bmatrix}$$

The viewpoint of 3 experts (decision makers) (k=3) is significant for data collection in this article. The data related to the expansion of human's activity is described in Table 4 and the data pertaining to biophysical criteria is shown in Table 5. Similarly, suppose the importance weight of attribute $X = \{x_1, x_2, ..., x_m\}$ given by the decision maker

$p_k (k = 1,2,..., K)$ is $\tilde{w}_i^k = (\alpha_i^k, \beta_i^k, \gamma_i^k, \delta_i^k)$ then the weights of the attributes and value of the alternatives with respect to each attribute can be calculated as follows:

Table 1. Linguistic variable for performance ratings of alternatives on qualitative attributes

Importance of values		Value of alternatives on each criterion	
Extremely Low (EL)	(0.2, 0.1, 0, 0)	Extremely Poor (EP)	(2, 1, 0, 0)
Very Low (VL)	(0.3, 0.2, 0.2, 0.1)	Very Poor (VP)	(3, 2, 2, 1)
Low (L)	(0.5, 0.4, 0.3, 0.2)	Poor (P)	(5, 4, 3, 2)
Medium (M)	(0.6, 0.5, 0.5, 0.4)	Medium (M)	(6, 5, 5, 4)
High (H)	(0.8, 0.7, 0.6, 0.5)	Good (G)	(8, 7, 6, 5)
Very High (VH)	(0.9, 0.8, 0.8, 0.7)	Very Good (VG)	(9, 8, 8, 7)
Extremely High(EH)	(1, 1, 0.9, 0.8)	Extremely Good (EG))	(10, 10, 9, 8)

Extremely Poor, Very Poor, Poor, Medium, Good, Very Good, Extremely Good

Table 2. Human activity criteria and indicators (The author, b)

criteria	indicators
Dominant land use & Adjacency	residential ‹industrial ‹garden & farmland
Heterogeneity	Urban Context
Accessibility	Urban access network access to edge
Disturbing factors	river pollution Parallel road Fragmentation

Table 3.Biophysical criteria and indicators (The author, b)

criteria	indicators
Patch conditions	Grain size patch size Patch form and spatial distribution
natural corridor (river)	width Bed and surface of water Bank of river Node River side
Soil & water supply	Other resource(subterranean canal, spring) Water Body

$$\tilde{w}_i = \frac{\tilde{w}_i^1 + \tilde{w}_i^2 \oplus ... \oplus \tilde{w}_i^K}{K} = \left(\frac{\sum_{k=1}^{K}\alpha_i^k}{K}, \frac{\sum_{k=1}^{K}\beta_i^k}{K}, \frac{\sum_{k=1}^{K}\gamma_i^k}{K}, \frac{\sum_{k=1}^{K}\delta_i^k}{K}\right)$$

and

$$\tilde{f}_{ij} = \frac{\tilde{f}_{ij}^1 + \tilde{f}_{ij}^2 \oplus ... \oplus \tilde{f}_{ij}^K}{K} = \left(\frac{\sum_{k=1}^{K}a_{ij}^k}{K}, \frac{\sum_{k=1}^{K}b_{ij}^k}{K}, \frac{\sum_{k=1}^{K}c_{ij}^k}{K}, \frac{\sum_{k=1}^{K}d_{ij}^k}{K}\right)$$

The experts' opinion about the importance of each criterion is in Table 6 and 7,

As stated above, a FMAGDM problem can be concisely expressed as the following decision matrix:

$$\tilde{Y} = (\tilde{f}_{ij})_{m\times n} = \begin{bmatrix} \tilde{f}_{11} & \tilde{f}_{12} & \cdots & \tilde{f}_{1n} \\ \tilde{f}_{21} & \tilde{f}_{22} & \cdots & \tilde{f}_{2n} \\ . & . & . & . \\ \tilde{f}_{n1} & \tilde{f}_{n2} & \cdots & \tilde{f}_{nm} \end{bmatrix}$$

Since the m˜ attributes may be measured in different ways, the decision matrix ˜Y needs to be normalized. The linear scale transformation is used here to transform the various attribute scales into a comparable scale.

$$\tilde{r}_{ij} = \left(\frac{a_{ij}}{d_i^{\max}}, \frac{b_{ij}}{d_i^{\max}}, \frac{c_{ij}}{d_i^{\max}}, \frac{d_{ij}}{d_i^{\max}}\right) \qquad (f_i \in F^1)$$

$$\tilde{r}_{ij} = \begin{cases} \left(\dfrac{a_i^{\min}}{d_{ij}}, \dfrac{a_i^{\min}}{c_{ij}}, \dfrac{a_i^{\min}}{b_{ij}}, \dfrac{a_i^{\min}}{a_{ij}}\right) & (a_i^{\min} \neq 0) \\ \left(1-\dfrac{d_{ij}}{d_i^{\max}}, 1-\dfrac{c_{ij}}{d_i^{\max}}, 1-\dfrac{b_{ij}}{d_i^{\max}}, 1-\dfrac{a_{ij}}{d_i^{\max}}\right) & (a_i^{\min} = 0) \end{cases} \qquad (f_i \in F^2)$$

Where

$$d_i^{\max} = \max_{1\le j\le n}\{d_{ij} \mid \tilde{f}_{ij} = (a_{ij}, b_{ij}, c_{ij}, d_{ij})\}$$

and

$$a_i^{\min} = \min_{1\le j\le n}\{a_{ij} \mid \tilde{f}_{ij} = (a_{ij}, b_{ij}, c_{ij}, d_{ij})\}$$

Denote $\tilde{r}_{ij}$ as $\tilde{r}_{ij} = (\mu_{ij}, \eta_{ij}, \rho_{ij}, \lambda_{ij})$. The normalization method mentioned above is to preserve the property that the range of a normalized trapezoid fuzzy number belongs to the closed interval [0, 1]. Therefore, the fuzzy decision matrix $\tilde{Y} = (\tilde{f}_{ij})_{m\times n}$ can be transformed into the normalized fuzzy decision Matrix:

$$\tilde{R} = (\tilde{r}_{ij})_{m\times n} = \begin{bmatrix} \tilde{r}_{11} & \tilde{r}_{12} & \cdots & \tilde{r}_{1n} \\ \tilde{r}_{21} & \tilde{r}_{22} & \cdots & \tilde{r}_{2n} \\ . & . & . & . \\ \tilde{r}_{n1} & \tilde{r}_{n2} & \cdots & \tilde{r}_{nm} \end{bmatrix}$$

Considering the different importance of each attribute, $\tilde{R}$ is transformed into the weighted normalized fuzzy decisionmatrix $\tilde{V}$:

$$\tilde{v}_{ij} = \tilde{w}_i \otimes \tilde{r}_{ij} = (\alpha_i\mu_{ij}, \beta_i\eta_{ij}, \gamma_i\rho_{ij}, \delta_i\lambda_{ij})$$

$$\tilde{V} = (\tilde{v}_{ij})_{m\times n} = \begin{bmatrix} \tilde{v}_{11} & \tilde{v}_{12} & \cdots & \tilde{v}_{1n} \\ \tilde{v}_{21} & \tilde{v}_{22} & \cdots & \tilde{v}_{2n} \\ . & . & . & . \\ \tilde{v}_{n1} & \tilde{v}_{n2} & \cdots & \tilde{v}_{nm} \end{bmatrix}$$

Where $\tilde{v}_{ij}$ is a trapezoid fuzzy number:

Obviously, all $\tilde{v}_{ij} = (\sigma_{ij}, \xi_{ij}, \upsilon_{ij}, \tau_{ij})$ are normalized positive trapezoid fuzzy numbers and their ranges belong to the closed interval [0, 1]. Then, we can define the fuzzy positive ideal solution f^+ and the fuzzy

Table 4. Linguistic numbers of experts for each option in human activities indicators

criteria	indicators	decision maker– zone1			decision maker– zone2			decision maker –zone3			decision maker –zone4		
		1	2	3	1	2	3	1	2	3	1	2	3
dominant Land use & Adjacency	Residential,industrial, garden & farmland	G	M	M	G	EG	VG	EP	EP	VP	M	P	M
	average	(6.7, 5.7, 5.3, 4.3)			(9, 8.3, 7.7, 6.7)			(2.3, 1.3, 0.7, 0.3)			(5.7, 4.7, 4.3, 3.3)		
Heterogeneity	Urban Context	VG	M	G	EG	EG	EG	P	VP	VP	G	G	M
	average	(7.7, 6.7, 6.3, 5.3)			(10, 10, 9, 8)			(3.7, 2.7, 2.3, 1.3)			(7.3, 6.3, 5.7, 4.7)		
accessibility	Urban accessibility network	G	G	M	M	M	VG	M	P	G	G	G	G
	average	(7.3, 6.3, 5.7, 4.7)			(6, 5, 5, 4)			(6.3, 5.3, 4.7, 3.7)			(8, 7, 6, 5)		
	access to edge	M	G	G	VG	M	EG	P	VP	P	G	VG	VG
	average	(7.3, 6.3, 5.7, 4.7)			(8, 7, 7, 6)			(4.3, 3.3, 2.7, 1.7)			(8.7, 7.7, 7.3, 6.3)		
Disturbing factors	river pollution	VG	G	VG	G	G	VG	EP	VP	EP	EP	EP	EP
	average	(3.7, 2.7, 2.3, 1.3)			(4, 3, 2, 1.3)			(9.7, 9.3, 8.7, 7.7)			(10, 10, 9, 8)		
	Parallel road	VG	G	G	G	M	EG	EP	EP	EP	M	G	M
	average	(4.3, 3.3, 2.7, 1.7)			(4.7, 3.7, 3.3, 2.3)			(10, 10, 9, 8)			(5.7, 4.7, 4.3, 3.3)		
	fragmentation	M	VG	M	M	M	VG	VP	VP	VP	G	G	VG
	average	(5, 4, 4, 3)			(5.7, 4.7, 4.3, 3.3)			(9, 8, 8, 7)			(4.3, 3.3, 2.7, 1.7)		

Table 5. Linguistic value of experts for each option in biophysical indicators

criteria	choices	decision maker– zone1			decision maker– zone2			decision maker –zone3			decision maker –zone4		
		1	2	3	1	2	3	1	2	3	1	2	3
Patch conditions	Grain size	G	VG	VG	EG	VG	EG	EP	EP	EP	G	M	P
	average	(8.7, 7.7, 7.3, 6.3)			(9.7, 9.3, 8.7, 7.7)			(2, 1, 0, 0)			(6.3, 5.3, 4.7, 3.7)		
	patch size & distribution	G	M	G	EG	EG	EG	VP	VP	P	VG	M	G
	average	(7.3, 6.3, 5.7, 4.7)			(10, 10, 9, 8)			(3.7, 2.7, 2.3, 1.3)			(7.7, 6.7, 6.3, 5.3)		
natural corridor (river)	width	VG	EG	VG	G	G	G	M	EP	G	G	G	M
	average	(9.3, 8.7, 8.3, 7.3)			(8, 7, 6, 5)			(5.3, 4.3, 3.7, 3)			(7.3, 6.3, 5.7, 4.7)		
	Bed and surface of water	G	VG	G	EG	G	VG	VP	P	VP	VG	G	M
	average	(8.3, 7.3, 6.7, 5.7)			(9, 8.3, 7.7, 6.7)			(3.7, 2.7, 2.3, 1.3)			(7.7, 6.7, 6.3, 5.3)		
	Bank of river	VG	VG	VG	P	M	G	EP	VP	VP	M	G	M
	average	(9, 8, 8, 7)			(6.3, 5.3, 4.7, 3.7)			(2.7, 1.7, 1.3, 0.7)			(6.7, 5.7, 5.3, 4.3)		
	Node	EG	G	VG	VG	M	EG	M	VP	P	G	P	M
	average	(9, 8.3, 7.7, 6.7)			(8.3, 7.7, 7.3, 6.3)			(4.7, 3.7, 3.3, 2.3)			(6.3, 5.3, 4.7, 3.7)		
Soil & water supply	River side	G	VG	VG	EG	VG	EG	VP	EP	VP	G	VG	VG
	average	(8.7, 7.7, 7.3, 6.3)			(9, 8.3, 7.7, 6.7)			(2.7, 1.7, 1.3, 0.7)			(8.7, 7.7, 7.3, 6.3)		
	Other resource	VG	EG	VG	G	V	VG	VP	VP	P	G	M	M
	average	(9.3, 8.7, 8.3, 7.3)			(5.7, 5, 4.7, 4)			(3.7, 2.7, 2.3, 1.3)			(6.7, 5.7, 5.3, 4.3)		
	Water Body	G	VG	G	VG	G	VG	P	VP	P	P	VP	P
	average	(8.3, 7.3, 6.7, 5.7)			(8.7, 7.7, 7.3, 6.3)			(4.3, 3.3, 2.7, 1.7)			(4.3, 3.3, 2.7, 1.7)		

Table 6. The opinion of the experts about the importance of human activities indicators

criteria	indicators	decision maker1	decision maker2	decision maker3	result
dominant Land use & Adjacent lands	**Residential, industrial, …**	VL	VL	L	(0.37, 0.27, 0.23, 0.13)
heterogeneity	**Urban Context**	L	EL	VL	(0.33, 0.23, 0.17, 0.10)
accessibility	**Urban accessibility network**	H	M	H	(0.73, 0.63, 0.57, 0.47)
	access to edge	M	L	H	(0.63, 0.53, 0.47, 0.37)
Disturbing factors	**river pollution**	EH	VH	EH	(0.97, 0.93, 0.87, 0.77)
	Parallel road	EH	EH	VH	(0.97, 0.93, 0.87, 0.77)
	fragmentation	VH	H	M	(0.77, 0.67, 0.63, 0.53)

Table 7. The opinion of the experts about the importance of biophysical criteria

criteria	indicators	decision maker1	decision maker2	decision maker3	result
Patch conditions	**Grain size**	H	M	L	(0.63, 0.53, 0.47, 0.37)
	patch size	VH	H	VH	(0.87, 0.77, 0.73, 0.63)
natural corridor (river)	**Width**	EL	VL	VL	(0.27, 0.17, 0.13, 0.07)
	Bed and surface of water	VH	VH	H	(0.87, 0.77, 0.73, 0.63)
	Bank of river	VH	H	VH	(0.87, 0.77, 0.73, 0.63)
	Node	M	L	M	(0.57, 0.47, 0.43, 0.33)
	River side	EH	EH	EH	(1 , 1 , 0.9, 0.8)
Soil & water supply	**Other resource**	L	L	H	(0.6, 0.5, 0.4, 0.3)
	Water Body	VL	EL	L	(0.33, 0.23, 0.17, 0.1)

negative ideal solution f^- whose weighted normalized fuzzy vectors are $\tilde{a}^+ = (\tilde{a}_1^+, \tilde{a}_2^+, ..., \tilde{a}_m^+)$ and $\tilde{a}^- = (\tilde{a}_1^-, \tilde{a}_2^-, ..., \tilde{a}_m^-)$, where $\tilde{a}_i^+ = (1,1,...,1) = 1$ and $\tilde{a}_i^- = (0,0,...,0) = 0$.

The distance of each alternative f_i from the fuzzy positive ideal solution and the fuzzy negative ideal solution can be calculated using the following equations, respectively:

$$D(f_i, f^+) = \sum_{i=1}^{m} d_2(\tilde{v}_{ij}, \tilde{a}_i^+) = \sum_{i=1}^{m} \sqrt{\frac{(1-\sigma_{ij})^2 + 2(1-\xi)^2 + 2(1-\upsilon)^2 + (1-\tau_{ij})^2}{6}}$$

and

$$D(f_i, f^-) = \sum_{i=1}^{m} d_2(\tilde{v}_{ij}, \tilde{a}_i^-) = \sum_{i=1}^{m} \sqrt{\frac{(\sigma_{ij})^2 + 2(\xi)^2 + 2(\upsilon)^2 + (\tau_{ij})^2}{6}}$$

Therefore the correlation coefficient of each alternative f_i (i = 1, 2, . . . , n) with ideal solution is calculated using the following equation:

$$C^*(f_i) = \frac{D^*(f_i, f^-)}{D^*(f_i, f^+) + D^*(f_i, f^-)}$$

The correlation coefficient of each zone is calculated by above mentioned formulas which are shown in Tables 8 and 9.

RESULTS & DISCUSSION

Human activity criteria and indicators - As Table 6 presents, according to the experts the highest rates are related to “parallel road”, “fragmentation” and “River pollution” indicators which have lowered the points. As a result, the ecological value of zone 3 has been decreased and zone 1 has become a more desirable zone. Among these criteria, the experts have assigned the lowest rates to “Heterogeneity”, and “Dominant land use and adjacent lands”. As a result,

Table 8. Correlation coefficient of each Zone regarding each criterion

Using human activity criteria		Using biophysical criteria	
Alternatives	orrelation coefficient $C^*(f_i)$	Alternatives	orrelation coefficient $C^*(f_i)$
Zone 1	0.386	Zone 1	0.445
Zone 2	0.382	Zone 2	0.461
Zone 3	0.174	Zone 3	0.144
Zone 4	0.325	Zone 4	0.364

Table 9. Correlation coefficient of each zone regarding all criteria

Alternatives	orrelation coefficient $C^*(f_i)$
Zone 1	0.419
Zone 2	0.426
Zone 3	0.157
Zone 4	0.347

these two criteria have had a lower impact on the decrease or increase of the zones' value. Moreover, according to Table 8, based on "human activities criteria", zones 1 and 2 have the highest correlation coefficient (0.386, 0.382) and zone 3 has the lowest one (0.174) which shows the adverse impact of construction and human activity on nature (Khoshk river). Therefore, the potential of the first two zones are higher in respect of having appropriate structures of landscape and the highest ecological value based on human activity criteria.

Biophysical criteria and indicators- Regarding "Biophysical Criteria", as Table 7 shows experts believe that the highest rate is related to Natural corridor ("River side", "bank of river and "Bed and surface of water" indicators) and "Patch size" which have decreased the ecological value of zone 3. Considering these criteria, zone 2 has the ideal conditions. Further, experts suggest that "width of river" and "Soil and Water supply" Criteria ("Other resource" and "Water Body" indicators) have a lower impact on the ecological appropriacy of the zone. Moreover, according to Table 8, based on "biophysical criteria", zone 2 owns the most degree (0.461) regarding appropriate natural condition in facing the urban development. Also the urban zone 3 has the least score (0.144) which shows the unsustainable condition of riverside and negative impact of urban developments on river, In which have led to the neglecting the river bank and penetration of constructions and roads to the riversides, body and basin of the river.

All criteria- Finally, all zones have been evaluated and prioritized according to the set criteria. Also, the influential factors and impact of each on the decrease or increase of the zone quality have been identified. regarding all criteria as shown in Table 9, the correlation coefficient of zones reveals that zone 2 (new development and garden zone) owns the highest correlation coefficient (0.426) and shows highest relative potential and more appropriate position in respect of all influential criteria in decision making, while zone 3 has the lowest correlation coefficient (0.157). In zone 3 most of the damage is the result of urban developments which have led to the neglecting the river bank, conducting the sewages and pollutions to the river, and penetration of constructions and roads to the body and basin of the river. All these have caused an inappropriate condition for different parts of the river and its surrounding areas. Regarding the obtained results through the group decision making fuzzy theory and TOPSIS method, in addition to detecting the landscape with the highest ecological value, the factors causing the degrading of the land are recognized. Therefore, the "disturbing factors" in the human activities criteria including the construction of the parallel roads close to the river even in the basin of it especially in the third zone (city center and old town) have been identified. These factors have contributed to the fragmentation of the riverside ecosystem (Table 6). Furthermore, the decrease in gardens' sizes, open and green patches, riverside and river's width- as a result of the extension of the construction in different parts of the city- are the important and effective factors for decreasing the ecological value of landscape(s).

CONCLUSION

Regarding passing the river over the different parts of the city, a) presence and accessibility to the natural resources (such as nodes, open and green patches, gardens, farmlands, parks), b) width of corridor and c) natural conditions of river and riverside are all very important and have high weight in determining the most valuable area (Table 5) because it is possible to transform this adjacent river space to the riverside ecosystem using restoration methods.

Also, riverside ecosystem can be helpful in connectivity among corridor and the open/ green patches. In conclusion, regarding the group decision making, some suggestions enhancing the environmental quality of the river and its basin will be presented which can lead to the improvement of the existing condition in respect of influential parameters on the city and the river quality. The suggestions are as follow:

- Ecological design and restoration in order to preserve the semi-natural condition of the river and its surrounding,
- Protection of the body, edges and sides of the river,
- Protection of the green patches (garden area), to increase the patch size and create connectivity among open and green patches,
- Prevention of the extension of urban and road construction to the river bank
- Stabilization of the compatible function to the surroundings and the change of incompatible functions, conservation and exploration of the potentials of gardens and green patches in the margins of the river in order to create the ecological connectivity and improve the environmental quality.

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