Journal of Urban and Environmental Engineering, v.8, n.1 p. 11-27, 2014

ISSN 1982-3932
doi: 10.4090/juee.2014.v8n1.011027

Journal of Urban and Environmental Engineering

www.journal-uee.org

A COMBINED FUZZY MCDM APPROACH FOR IDENTIFYING THE SUITABLE LANDS FOR URBAN DEVELOPMENT: AN EXAMPLE FROM BANDAR ABBAS, IRAN

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Received 7 May 2014; received in revised form 4 July 2014; accepted 18 July 2014

Abstract: This study aims at identifying the suitable lands for urban development in Bandar Abbas city based on its real world use regarding specific criteria and sub-criteria. The city of Bandar Abbas is considered as the most important commercial and economic city of Iran. It is also considered as one of the major cities of Iran which has played a pivotal role in the country's development and progress in recent years especially after the end of Iran-Iraq war owing to its embracing the country's main commercial ports. This process has caused the immigration rate into the city to rise significantly over the past 20 years. Thus, the development of the city is meanwhile considered as a high priority. Bandar Abbas city does not have a rich capacity for growth and development due to its special geographical situation being located in coastal border. Among the limitations placed in the city's development way, natural limitations (heights and sea shore) in the northern and southern parts of the city and structural limitations (military centers) in the east and west sides of the city may be referred. Therefore, identifying the suitable lands for urban development within Bandar Abbas city limits is becoming an essential priority. Therefore, different quantitative and qualitative criteria have been studied in order to select and identify these lands. The structures of qualitative criteria for most parts involve ambiguities and vagueness. This leads us to use Fuzzy logic in this study as a natural method for determining the solutions for problems of Multi-criteria decision making (MCDM). In the current research, a combination of MCDM methods has been presented for analysis. To assignee weights of the criteria Fuzzy AHP (analytic hierarchy process) is used for land selection and Fuzzy TOPSIS (method for order priority by similarity to ideal solution) is utilized to choose the alternative that is the most appropriate through these criteria weights. The sensitivity analysis of the results is included in the research.

Keywords: Urban development, Suitable land, Fuzzy AHP, Fuzzy TOPSIS

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INTRODUCTION

Today, due to the population growth and urbanization sprawl, it is necessary to determine suitable lands for developing urban land uses (Sheppard *et al.*, 2013; Brenner, 2013). Urban sprawl and limited lands have increased the demand for developing and improving the urban land uses. Therefore, determining suitable lands for developing and improving the quality of residence is of high importance. As a developing country, Iran is confronted with a rapid growth of urbanization rate (population growth and sprawling the cities' limits) in the capital and medium cities such as Bandar Abbas (Rafiee *et al.*, 2009). The number of towns and cities in Iran has witnessed a significant increase in recent decades from 199 cities in 1956 to 1200 cities in 2012 (Ministry of Roads and Urban Development, 2012). The urban development has occurred in many aspects in form of official and non-official developments as residential towns and increased construction density.

Cities in Iran are for the most part confronted with scarcity of suitable lands for development due to the accelerated growth of urbanization and the cities' sprawling. For instance, the city of Bandar Abbas owing to its location which is in vicinity of the major commercial port of the country and the special economic zone during the past six decades has undergone a population increase from 17710 people in 1956 to 518345 people in 2012 (Iranian Statistic Center, 2012). Also, the city's area has risen from 5 km^2 to about 85 km^2 between 1956 and 2012. The significant growth of Bandar Abbas city has occurred as a result of its strategic position as the country's main port of export and import. Nowadays, this unbalanced sprawling of the urban lands and excessive population growth has caused Bandar Abbas city to confront with the scarcity of suitable lands for developing and increased demands for residence. Thus, specifying the suitable lands as urban districts, for the purpose of development and renovation is necessary and important regarding the mentioned obstacles. Developing the residential lands' uses endangers the environmental and ecological resources. Therefore, simulation of changes in urban lands' use and recognition of the suitable lands for developing is of high importance for future planning and taking correct and rational decisions by municipal officials and municipalities. Identifying and selecting the suitable lands provides the possibility of simulation and correct and rational estimation for planners, designers and users according to the existent reality. Moreover, it enables the planners to determine the efficiency and fitness of the lands for development before the plan begins to be implemented. Therefore, in selecting suitable lands we should consider different factors such as: compatibility, utility, availability, quality and efficiency. Moreover, an investigation of the parameters influencing the population, feasibility analysis and market demand is necessary.

All the above-mentioned criteria should be analyzed in terms of their influence on each other and their relative importance in the process of selecting suitable lands. The recognition of the evaluating criteria and definition of their influence on each other is described and determined according to assessing their importance and the multi-criteria decision making (MCDM) method. Generally, MCDM method includes the decision making process on the basis of different criteria and objectives (Vaidya & Kumar, 2006; Saaty & Vargas, 1991). A large number of developed methods are dependent on the concepts of measurement precision as well as assessment correctness. However, many of these selective parameters could not be determined correctly and precisely, and the objectives are often contradictory. Therefore, selection of a solution depends considerably on what the decision maker prefers. So, the evaluation of data concerning the locations of the suitable lands for urban development is carried out according to different criteria that are subjective and the weight of each criterion largely stated in linguistic conditions. This leads us to put forward the fuzzy logic as a very natural method in solving such problems. The methods of MCDM could similarly be used along with fuzzy methods in order to confront with uncertainties in the homogeneous data.

In the current research, a combination of fuzzy and MCDM methods has been applied for evaluating and identifying the location of the suitable lands for urban development. Analytic hierarchy process (AHP) has been used for computing criteria's weights; it is a prioritization method based on the similarity to the ideal solution (TOPSIS) for ranking the alternative locations (Chu & Lin, 2003). TOPSIS model is indeed used for recognizing the solutions as close to a perfect applicable step as possible as well as showing the solutions' priorities. There are various methods for weight computation; however, AHP has various advantages. One of the most significant benefits and capabilities of AHP is that it is based on the binary (pair wise) comparison. Moreover, AHP computes the inconsistency index that is considered as inconsistency rate of the decision maker. Anyway, sometimes a lot of binary (pair wise) comparisons should be made by a decision maker and this status, particularly in Fuzzy AHP, leads to impracticality of the process of using AHP to decrease the number of binary comparisons, and alternative ranking and Fuzzy TOPSIS technique is applied (Önüt *et al.*, 2010). This method is regarded as one of the most efficient methods for identifying and selecting the suitable lands for urban development. The purpose of the current research is to recognize the suitable lands for development based on the historical and cultural, ecological and environmental, economic, social, physical, structural and accessibility criteria in Bandar Abbas city. Due to the accelerated growth of urbanization, population increase and limited lands, identification of the suitable lands for urban development is essential and important in the city of Bandar Abbas. Fuzzy TOPSIS method has been used and for computing the criteria's weights, Fuzzy AHP method has been employed. The term TOPSIS is an acronym made for "Technique for Order Preference by Similarity to Ideal Solution". TOPSIS method is among the most useful multi-criteria methods of decision making in investigating the real world problems which has been first suggested by Hwang & Yoon, 1981.

TOPSIS model is used widely in multi-factor analyses and multi-criteria methods of decision making owing to its logical functionality, the possibility of simultaneous proposing the ideal and non-ideal solutions and having an easy and programmable method of computation (Karsak, 2002). This method depends on the concept of the positive perfect alternative to attain the grade a level for all the characteristics. At the same time, it has also the negative ideal conditions with all the descriptive low value quantities. In Fuzzy TOPSIS model, descriptive values are displayed on the basis of the fuzzy numbers. Through applying this method, the expert who makes decision, allocates the fuzzy numbers to the different proposed hypotheses and considers the relationship between different criteria for integrating the used methods and ensuring the increased precision of decision making. According to the research literature, a few articles have studied the theories and literature concerning the locating of the suitable lands for urban development. Research literature so far has mostly focused on the recognition of the urban lands for developing the necessary lands' uses in urban level. The relevant criteria have been essentially oriented toward determining special use and the effective factors in recognizing the same type of lands' use. However, in this study, we have dealt with the identification of the suitable lands for urban development on the basis of historical and cultural, ecological, environmental, physical, economic , social, structural and accessibility criteria. Some instances which may be referred to include: Martinuzzi *et al. (*2007) which using the satellite images attempted to recognize Puerto Rico city's lands' use; and then using population density data and the region's land use, they attempted to identify the suitable lands for urban development in the region under study. The obtained results determine the lands' user capitation based on the household size and population density in the developed and non-developed regions. S Awasthi & Chauhan (2012) proposed a decision-making supporting system based on the integration of AHP and Fuzzy TOPSIS models for planning in the sustainable development of the urban services. In this study, according to the effective factors such as administrative factors, transportation network, service firms, and final customers, they studied the environmental effects of this process and also developing a decision-making supporting system based on the mentioned models. F. Hosseinali *et al. (*2013) using the agent-based model and the residential regions factor along with the sum of lands' uses, attempted to identify the suitable lands for development in Qazvin city. Since the aim of this study was to identify and simulate the suitable urban lands for residential development, it paid little attention to other effective criteria in the process of urban development. Fu Yang *et al. (*2008) utilized the location analysis system for administering land use based on GIS and also multi-criteria evaluation model. Moreover, in this analysis, according to the urban management and the master plan, optimizing the distribution of the suitable lands for development has been carried out. In this process, after identifying and classifying the suitable lands, their degree of importance and also distribution priorities in the region of study, Changsha City, have been determined.

In the research literature, there are numerous cases of evaluating the location of the urban uses and selecting the suitable model for investigating and identifying them. Furthermore, some of them focus on identifying the suitable lands for urban development according to the effective criteria. However, a few studies have used MCDM method on the basis of multiple criteria, humanistic judgment, being tangible and intangible on identifying the suitable lands for urban development. Although a few studies have been done on identifying the suitable lands for urban development, there is no evidence suggesting that urban development process in Iran or in an urban region has ever been carried out according to 7 criteria for evaluation as well as by making use of AHP and TOPSIS models in a fuzzy environment. Therefore, this is regarded as the most important motivation for solving the problem of identifying suitable lands for urban development. In the next stage, through Fuzzy AHP model, we have used triangular fuzzy numbers for all the binary comparison matrices. For this purpose, the criteria's weights were computed based on the triangular fuzzy numbers and then the criteria's fuzzy weights were identified for determination of ranking of the alternatives.

METHODOLOGY

A further step is describing the joint methodology that is used in the current research. The methodology is made up of two parts. In part one; we use the criteria weights are calculated by Fuzzy AHP. In part two, Fuzzy TOPSIS is applied to rank and choose the alternatives. In the subsections below, Fuzzy TOPSIS, theoretical descriptions of the Pathway analysis and Fuzzy AHP are explained. **Figure 1** shows the methodology used in this research. Suitable lands were identified by creating a geodatabase with data collection and geospatial analysis.

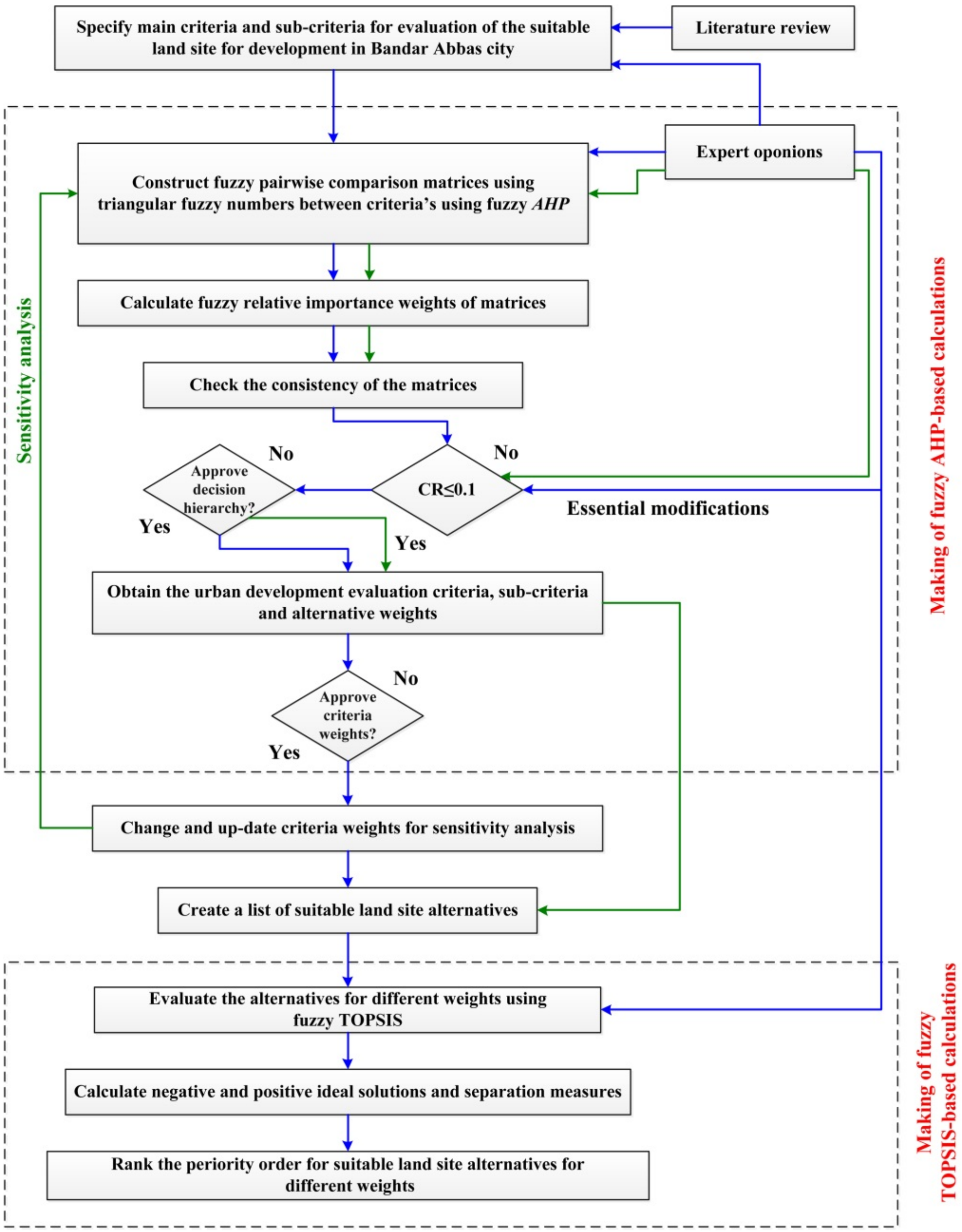


Fig. 1 The methodology used in this research.

AHP method

In the 1980s Thomas L. Saaty developed The Analytic Hierarchy Process (AHP) method. AHP considers that evaluation criteria can be entirely shown in a hierarchical structure. The procedure paves the way to include judgments on intangible qualitative criteria beside quantitative criteria which are tangible (Badri, 2001). The AHP method is based on three principles: first of all, structure of the model; second, comparative judgment of the alternatives and the criteria; third, combination of the priorities. In the literature resolving many intricate decision-making problems AHP is normally implemented (Banai, 1989; Estoque & Murayama, 2010, Guiqin *et al.*, 2009; Itami RM *et al.*, 2000; Radiarta *et al.*, 2008; Tudes *et al.*, 2010).

In phase one, a difficult decision problem is organized as a hierarchy. Firstly, complex multi-criteria decision-making problem is broken down into a hierarchy of relevant decision elements (decision alternatives, and criteria) by AHP. With the AHP, the alternatives, criteria and objectives, are organized in a hierarchical structure equally to a family tree. Three levels are considered for a family tree at minimum: at the highest, overall goal of the problem, multiple criteria that define alternatives in the medium, and at the lowest decision alternatives (Albayrak & Erensal, 2004).

The second phase is the criteria and the judgment of the alternatives. When detachment has been the problem and the hierarchy is shaped, the process of prioritization begins so as to specify the relative significance of the

Table 1. Linguistic variables describing weights of the criteria and values of rating.

Linguistic scale for importance	Fuzzy number for the Fuzzy AHP	Membership function	Domain	Triangular fuzzy scale (l,m,u)
Just equal				(1.0,1.0,1.0)
Equal importance	$\tilde{1}$			(1.0,1.0,3.0)
Weak importance of one over another	$\tilde{3}$	$\mu_M(x) = (3-x)/(3-1)$ $\mu_M(x) = (x-1)/(3-1)$	$1 \le x \le 3$ $1 \le x \le 3$	(1.0,3.0,5.0)
Essential or strong importance	$\tilde{5}$	$\mu_M(x) = (5-x)/(5-3)$ $\mu_M(x) = (x-3)/(5-3)$	$3 \le x \le 5$ $3 \le x \le 5$	(3.0,5.0,7.0)
Very strong importance	$\tilde{7}$	$\mu_M(x) = (7-x)/(7-5)$ $\mu_M(x) = (x-5)/(7-5)$	$5 \le x \le 7$ $5 \le x \le 7$	(5.0,7.0,9.0)
Extremely preferred	$\tilde{9}$	$\mu_M(x) = (9-x)/(9-7)$ $\mu_M(x) = (x-7)/(9-7)$	$7 \le x \le 9$ $7 \le x \le 9$	(7.0,9.0,9.0)
If factor *i* has one of the above numbers assigned to it when compared to factor j, then *j* has the reciprocal value when compared with *i*				Reciprocals of above $M_1^{-1} \approx (\frac{1}{u_1},\frac{1}{m_1},\frac{1}{l_1})$

criteria in each level. The pairwise comparison begins from the middle level and ends at the lowest level, alternatives. The criteria are compared pairwise, in each level, based on their levels of effect and according to the identified criteria in the higher level (Albayrak & Erensal, 2004).

Multiple pairwise comparisons in AHP are based on a nine-level standardized comparison scale (**Table 1**). Let $C = \{Cj \mid j = 1,2,\ldots,n\}$ be the set of criteria. The consequence of the pairwise comparison on n criteria can be summarized in an $(n \times n)$ evaluation matrix A in which every element a_{ij} $(i,j = 1,2,\ldots,n)$ is the proportion of criteria weights, as shown:

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix}, a_{ii} = 1, a_{ji} = \frac{1}{s_{ij}}, a_{ij} \neq 0 \quad (1)$$

At the final phase, the mathematical procedure begins to regularize and for each matrix find the relative weights. The right eigenvector (w) gives the relative weights corresponding to the biggest eigenvalue(λ_{max}), as:

$$A_w = \lambda_{max} W \quad (2)$$

Providing the pairwise comparisons are completely consistent, the matrix A has rank 1 and $\lambda_{max} = n$. In this situation, through normalizing any of the rows or columns, weights can be attained (Wang & Yang, 2007).

It must be stated that the quality of the result of the AHP is closely relevant to the consistency of the pairwise comparison judgments. The relation between the admissions of $A: a_{ij} \times a_{jk} = a_{ik}$ can define the consistency. The consistency index (CI) is:

$$CI = (\lambda_{max} - n)/(n-1) \quad (3)$$

he last consistency ratio (CR), practice of which allow everyone to realize if the assessments are sufficiently consistent, is calculated as the ratio of the CI and the random index (RI), as presented.

$$CR = CI/RI \quad (4)$$

Saaty (1980) proposes that if the ratio surpasses 0.1, the set of judgments might be so inconsistent that it cannot be dependable. Thus, a CR under 0.1 or 10% is acceptable. When the assessment is inconsistent, the procedure is repeated until the CR is within the desired range.

Fuzzy AHP

In the suggested methodology, the AHP with its fuzzy extension, that is Fuzzy AHP is useful to attain more conclusive judgments by making the machine tool selection criteria a priority and weighting them in the attendance of vagueness. There are various Fuzzy AHP applications in the literature that suggest systematic methods for selection of alternatives and justification of problem by using hierarchical structure analysis and fuzzy set theory. It normally suits Decision makers to express interval judgments rather than fixed value judgments owing to the fuzzy nature of the comparison procedure (Bozdag *et al.*, 2003). This research which is presented by Chang (1992) is combination on a Fuzzy AHP method, in which triangular fuzzy numbers are desired for pairwise comparison scale. Extent analysis method is chosen for the synthetic extent values of the pairwise comparisons. Some papers (Kahraman *et al.*, 2003; Kahraman *et al.*, 2004) used the Fuzzy AHP process according to extent analysis method and presented the way it can be applied to selection problems. The scheme of the fuzzy sets and extent analysis method for the Fuzzy AHP are as follows.

A fuzzy number is a particular fuzzy set $F = \{(x, \mu_F(x), x \in R\}$, where x takes its values on the real line, $R: -\infty \leq x \leq \infty$ and $\mu_F(x)$ is a continuous mapping from R to the closed interval [0, 1]. A triangular fuzzy number (TFN) states the relative strength of each pair of features in the same hierarchy and can be indicated as $M = (l, m, u)$, where $l \leq m \leq u$. The parameters l; m; u; specify the smallest possible value, the most capable value, and the largest possible value respectively in a fuzzy result. Triangular method membership function of M fuzzy number can be explained as in **Eq. (5)**. When$l = m = u$, it is a nonfuzzy number by convention.

$$\mu_M(x) = \begin{cases} 0 & x < l \\ (x\text{-}l)/(m\text{-}l) & l \leq x \leq m \\ (u\text{-}x)/(u\text{-}m) & m \leq x \leq u \\ 0 & x > u \end{cases} \quad (5)$$

A linguistic variable is the one with its values expressed in an artificial or natural language. The concept of a linguistic variable offers means of rough feature of phenomena that are too intricate or too inaccurate to be disposed to explanation in conventional quantitative terms. The chief uses of the linguistic method exist in the area of humanistic systems particularly in the fields of linguistics, human decision process, artificial intelligence, pattern recognition, medical diagnosis, economics, psychology, information retrieval and relevant fields (Bellman & Zadeh, 1977; Zadeh, 1975).

In this research, the linguistic variables used in the model can be stated in positive Triangular Fuzzy Number (TFNs) for each of the criteria as in **Fig. 2**. The linguistic variables corresponding TFNs and the matching membership functions are given in **Table 1**. Suggested methodology uses a Likert Scale of fuzzy numbers starting from $\tilde{1}$ to $\tilde{9}$ symbolized with tilde (~) for the Fuzzy AHP method (**Fig. 3**). **Table 1** displays the AHP and Fuzzy AHP comparison scale considering the linguistic variables that depict the significance of criteria and alternatives to improvement the scaling scheme for the judgment matrices. By applying TFNs via pairwise comparison, the fuzzy judgment matrix $\tilde{D}(d_{ij})$ can be stated mathematically as:

$$\tilde{D} = \begin{Bmatrix} 1 & \tilde{d}_{12} & \tilde{d}_{13} & \cdots & \tilde{d}_{1(n\text{-}1)} & \tilde{d}_{1n} \\ \tilde{d}_{21} & 1 & \tilde{d}_{23} & \cdots & \tilde{d}_{2(n\text{-}1)} & \tilde{d}_{2n} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots & \cdots & \vdots & \vdots \\ \tilde{d}_{(n\text{-}1)1} & \tilde{d}_{(n\text{-}1)2} & \tilde{d}_{(n\text{-}1)3} & \cdots & 1 & \tilde{d}_{(n\text{-}1)n} \\ \tilde{d}_{n1} & \tilde{d}_{n2} & \tilde{d}_{n3} & \cdots & \tilde{d}_{n(n\text{-}1)} & 1 \end{Bmatrix} \quad (6)$$

The judgment matrix $\tilde{D}$ is a $n \times n$ fuzzy matrix containing fuzzy numbers d_{ij}.

$$\tilde{d}_{ij} = \begin{cases} 1, & i = j \\ \tilde{1}, \tilde{3}, \tilde{5}, \tilde{7}, \tilde{9} \text{ or } \cdots \tilde{1}^{-1}, \tilde{3}^{-1}, \tilde{5}^{-1}, \tilde{7}^{-1}, \tilde{9}^{-1} & i \neq j \end{cases} \quad (7)$$

Let $X = \{x_1, x_2, \ldots, x_n\}$ be an object set, whereas $U = \{u_1, u_2, \ldots, u_m\}$ is an aim set. Based on fuzzy extent analysis, the method can be completed with respect to each object for each corresponding aim, g_i, resulting in m extent analysis values for each object, given as $M_{g_i}^1, M_{g_i}^2, \ldots, M_{g_i}^m, i = 1,2,\ldots,n$, where all the $M_{g_i}^j$ $(j = 1,2,\ldots,m)$ are TFNs signifying the performance of the object x_i with regard to each aim u_j. The following is the details of Chang's extent analysis steps (Chang, 1992; Bozbura *et al.*, 2007; Kahraman *et al.*, 2003, 2004):

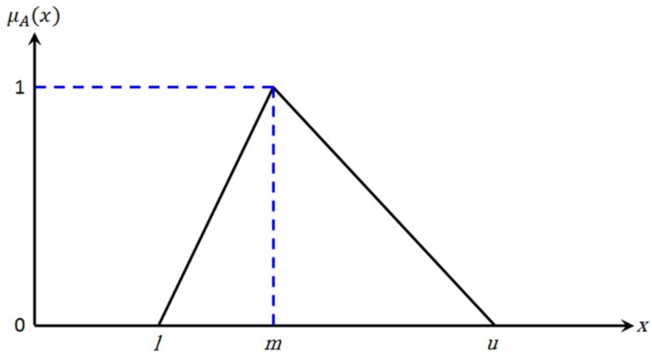


Fig. 2 Schematic diagram of fuzzy triangular number A= (l,m,u).

Step 1: The value of fuzzy synthetic extent according to the ith object is specified as:

$$S_i = \sum_{j=1}^{m} M_{g_i}^j \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^j\right]^{-1} \quad (8)$$

To achieve $\sum_{j=1}^{m} M_{g_i}^j$, apply the fuzzy addition operation m extent analysis values for a specific matrix such that

$$\sum_{j=1}^{m} M_g^j = \left(\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j\right) \quad (9)$$

and to obtain $\left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^j\right]^{-1}$, the fuzzy addition operation of $M_{g_i}^j (j = 1,2, m)$ values is performed such as:

$$\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^j = \left(\sum_{i=1}^{n} l_i, \sum_{i=1}^{n} m_i, \sum_{i=1}^{n} u_i\right) \quad (10)$$

and then calculate the inverse of the vector in Eq. (10) such that

$$\left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^j\right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} u_i}, \frac{1}{\sum_{i=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} l_i}\right) \quad (11)$$

Step 2: As $M_1 = (l_1, m_1, u_1)$ and $M_2 = (l_2, m_2, u_2)$ are two triangular fuzzy numbers, the degree of possibility of $M_2 = (l_2, m_2, u_2) \geq M_1 = (l_1, m_1, u_1)$ is specified as:

$$V(M_2 \geq M_1) = \sup_{y \geq x}[\min\ (\mu_{M1}(x), \mu_{M2}(y))] \quad (12)$$

and can be stated as follows:

$$V(M_2 \geq M_1) = hgt(M_1 \cap M_2) = \ \mu_{M_2}(d) \quad (13)$$

$$= \begin{cases} 1, if \quad m_2 \geq m_1 \\ 1, if \quad l_1 \geq u_2 \\ \frac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)}, Otherwise \end{cases} \quad (14)$$

Figure 3 demonstrates Eq. (11) where d is the ordinate of the highest intersection point D between $\mu_{M_1}$and μ_{M_2}. To compare M_1 and M_2, we need both the values of $V(M_1 \geq M_2)$ and $V(M_2 \geq M_1)$.

Step 3: The degree possibility of a convex fuzzy number to be greater than k convex fuzzy numbers $M_i\ (i\ =\ 1,2, \ldots, k)$ can be specified by

$$V(M\ \geq\ M_1, M_2, \ldots, M_k) = V[(M\ \geq\ M_1)]\ and\ V[(M\ \geq\ M_2) and\ (M\ \geq\ M_k)] = \min V\ (M\ \geq\ M_i), i = 1,2,3, \ldots, k. \quad (15)$$

Let's consider $d(A_i) = \min V(S_i \geq S_k)$ for $k = 1,2, \ldots, n; k \neq i$. then the weight vector is given by

$$W' = (d'(A_1), d'(A_2), \ldots \ldots, d'(A_n))^T \quad (16)$$

where $A_i = \ (i = 1, 2, \ldots n)$ are n elements.

Step 4: Via normalization, the normalized weight vectors are

$$W = (d(A_1), d(A_2), \ldots \ldots, d(A_n))^T \quad (17)$$

where W is a non-fuzzy number.

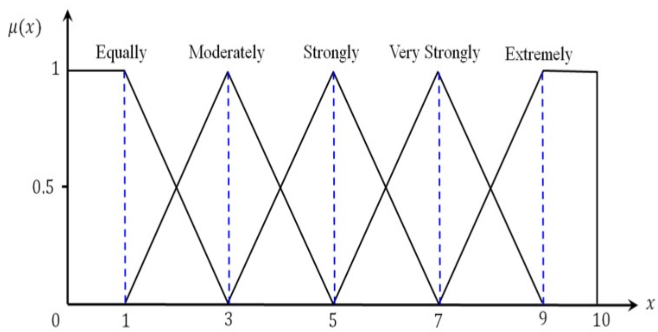


Fig. 3 Linguistic variables for the importance of each criterion.

Fuzzy TOPSIS

The TOPSIS method was first suggested by Hwang & Yoon (1981). As the central notion of this method is that the selected alternative should be the closest in terms of distance from the positive ideal solution and from negative ideal solution it should have the extreme distance. Positive ideal solution is the one that through which the advantage criteria is maximized and rate criteria are minimized, while the rate criteria is maximized and the advantage criteria is minimized by negative ideal solution (Wang & Elhag, 2006). In the typical TOPSIS method, the ratings of alternatives and the weights of the criteria are accurately known and in the assessment procedure crisp values are used. Though, in many situations crisp data are insufficient to model real-life decision problems. Consequently, the Fuzzy TOPSIS method is offered where ratings of alternatives and the weights of criteria are assessed by linguistic variables characterized by fuzzy numbers to tackle the absence in the traditional TOPSIS. In the current study what is considered is the extension of TOPSIS method offered by Chen (2000) & Chen *et al* (2006). The following steps can describe algorithm of this method:

Step 1: Let $\tilde{a} = (l_1, m_1, u_1)$ and $\tilde{b} = (l_1, m_1, u_1)$ be two TFNs, then the vertex method is defined to compute the distance between them, as:

$$d(\tilde{a}, \tilde{b}) = \sqrt{\frac{1}{3}[(l_1 - l_2)^2 + (m_1 - m_2)^2 + (u_1 - u_2)^2]} \quad (18)$$

The following sets can describe the problem:

i. A set of J possible candidates called $A = \{A_1, A_2, \ldots, A_J\}$.
ii. A set of n criteria, $C = \{C_1, C_2, \ldots, C_j\}$.
iii. A set of priority ratings of $A_j\ (j = 1,2,3, \ldots, J)$ with respect to criteria $C_i\ (i = 1,2,3, \ldots, n)$ called $\tilde{X} = \{\tilde{x}_{ij}\ i = 1,2,3, \ldots, n, j = 1,2,3, \ldots, J\}$.
iv. A set of importance weights of each criterion $w_i (i = 1,2,3, \ldots, n)$.
v. As expressed above, problem matrix format can be expressed as follows:

$$\widetilde{D} = \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \cdots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & \cdots & \tilde{x}_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ \tilde{x}_{J1} & \tilde{x}_{J2} & \cdots & \tilde{x}_{Jn} \end{bmatrix} \quad (19)$$

$$\widetilde{W} = [\widetilde{w}_1, \widetilde{w}_2, \ldots, \widetilde{w}_n] \quad (20)$$

Step 2: After the fuzzy decision matrix is constructed, it is normalized. The linear scale transformation can be used instead of using complicated normalization formula of typical TOPSIS to transform different criteria scales into a comparable scale. Hence, the normalized fuzzy decision matrix $\tilde{V}$ can be attained:

$$\tilde{V} = \left[\tilde{v}_{ij}\right]_{n\times J}\ i = 1,2,\dots,n, j = 1,2,\dots,J$$

Where

$$\tilde{v}_{ij} = \tilde{x}_{ij}\ (.) w_i. \tag{21}$$

The outline of Fuzzy TOPSIS steps is as follows based on the above concisely summarized fuzzy theory.

Step 3: Select the linguistic ratings ($\tilde{x}_{ij}\ i = 1,2,3,\dots,n, j = 1,2,3,\dots,J$) for alternatives according to criteria. The fuzzy linguistic rating($\tilde{x}_{ij}$) conserves the property that the ranges of normalized TFNs depend on [0, 1]; therefore, there is no need for normalization. Let $\tilde{x}_{ij} = \left(a_{ij}, b_{ij}, c_{ij}\right), \tilde{x}_j^- = (a_j^-, b_j^-, c_j^-)$ and $\tilde{x}_j^* = (a_j^*, b_j^*, c_j^*)$. We have

$$\tilde{r}_{ij} = \begin{cases} \tilde{x}_{ij}(\div)\tilde{x}_j^* = \left(\frac{a_{ij}}{a_j^*}, \frac{b_{ij}}{b_j^*}, \frac{c_{ij}}{c_j^*}\right) \\ \tilde{x}_j^-\ (\div)\tilde{x}_{ij} = \left(\frac{a_j^-}{a_{ij}}, \frac{b_j^-}{b_{ij}}, \frac{c_j^-}{c_{ij}}\right) \end{cases} \tag{22}$$

Step 4: Compute the weighted normalized fuzzy decision matrix. The weighted normalized value $\tilde{v}_{ij}$ calculated by **Eq. (21)**.

Step 5: Find positive ideal (A^*) and negative ideal (A^-) solutions. The fuzzy positive ideal solution $(FPIS, A^*)$ and the fuzzy negative-ideal solution $(FNIS, A^-)$ are illustrated in the following equations:

$$A^* = \{\tilde{v}_1^*, \tilde{v}_2^*, \dots, \tilde{v}_i^*\} = \left\{\left(\max_j v_{ij} | i \in I'\right)\right\}, \left\{\left(\min_j v_{ij} | i \in I''\right)\right\},\ i = 1,2,\dots,n\ j = 1,2,\dots,J \tag{23}$$

$$A^- = \{\tilde{v}_1^-, \tilde{v}_2^-, \dots, \tilde{v}_i^-\} = \left\{\left(\min_j v_{ij} | i \in I'\right)\right\}, \left\{\left(\max_j v_{ij} | i \in I''\right)\right\},\ i = 1,2,\dots,n\ j = 1,2,\dots,J \tag{24}$$

where I' is related to advantage criteria and I'' is related to cost criteria.

Step 6: Compute the distance of each alternative from A^* and A^- using the following equations:

$$D_j^* = \sum_{j=1}^{n} d\left(\tilde{v}_{ij}, \tilde{v}_i^*\right)\ \ j = 1,2,\dots,J \tag{25}$$
$$D_j^- = \sum_{j=1}^{n} d\left(\tilde{v}_{ij}, \tilde{v}_i^-\right)\ \ j = 1,2,\dots,J \tag{26}$$

Step 7: Calculate similarities to ideal solution.

$$CC_j = \frac{D_j^-}{D_j^* + D_j^-}\ \ j = 1,2,\dots,J \tag{27}$$

Step 8: Rank preference order. Choose an alternative with maximum CC_j^* or rank alternatives according to CC_j^* in descending order.

Study Area

As a capital city of Hormozgan Province, Bandar Abbas which is a commercial port city is located on the southern coast of Iran, at the mouth of Persian Gulf. The area under study is between 27°8'N to 27°15'N latitude and 56°13' to 56°22' longitudes. The area is approximately 100 Km² of land area encompassing Hormozgan province, IRAN, and includes 4 regions and 70 districts (**Fig. 4**). This city has a strategic position on

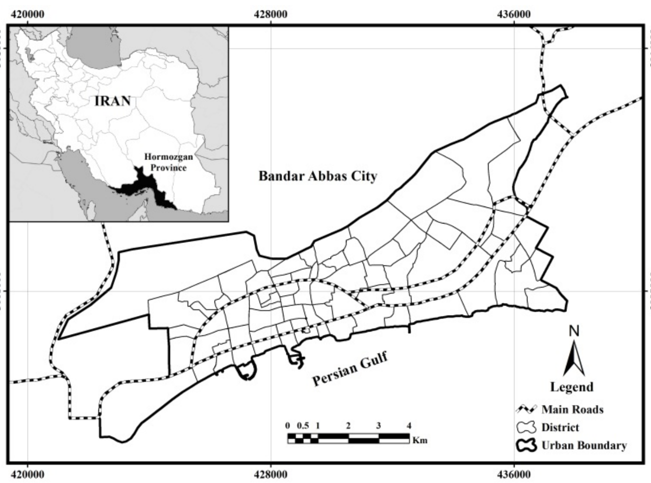


Fig. 4 Location of the study area.

Straits of Hormuz, in which the main base of the Iranian Navy is located. The ground on which Bandar Abbas lies is flat and the city has an average altitude of 9 m above sea level. The highest areas close to the city is Geno Mountain, which is located 17 km north of the city, and Pooladi Mountain, 16 km to the northwest of the city. River Shoor is the nearest river to Bandar Abbas, which rises in Geno Mountain and ends in the Persian Gulf, which is 10 km from the city. It is capital city of Bandar Abbas County. Population of Bandar Abbas was 0.54 million in the year 2012, and it is estimated to be 0.85 million in 2030, as per the current growth rate. Urban authorities must know urban sprawl phenomenon of Bandar Abbas, the way it is predicted to move in the near future in order to effectively plan for urban growth in the future and its distribution. Heavy industries (commercial ports, fishing ports, oil and gas refinery and industrial area) that occupies 74% of the active population are considered the most noteworthy economic activities, and Bandar Abbas has always been a popular tourist destination, both domestically and internationally.

Both activities besides the administrative functions resulting from situation of the capital of the province served as a factor that appeal to a large number of immigrants from the province of Hormozgan and even from the whole country. Hence, the growth that the city has witnessed is so rapid that it is recoded as the city with the largest growth in urban land development among the other cities in Iran with a population bigger than 300,000 residents.

Suitable land selection for urban development in Bandar Abbas

By beginning of the 20th century, and economic growth and development in Iran, Bandar Abbas city has undergone extensive changes in urban development, population increase and economic growth. Therefore, the structural development of the city has been prioritized. The districts of the city of Bandar Abbas are generally classified into three groups of developed, under-developed and non-developed districts. Unfortunately, developed districts with precedence less than two decades, due to lack of any infrastructural urban facility and being distant from the commercial centers have not become an urban sprawling center. And on the other hand, non-developed or less-developed - called otherwise- districts, regarding their precedence and their basic role in formation and creation of the city have been vanishing; this is due to being neglected and not being improved in terms of the compatible urban uses. Therefore, in this study, on the basis of all the urban growth and development aspects, the developing (under-developed) districts have been studied and analyzed owing to their vicinity to the commercial, tourist, administrative centers and natural attractions giving them a high capacity for development. According to the mentioned issues, selection and identification of the suitable lands for urban development in the districts of Bandar Abbas city has been carried out based on the historical and cultural, ecological and environmental, social, economic, physical, structural and accessibility criteria.

Data collection

The primary objective of the present study is the feasibility analysis of the suitable lands according to the specified criteria and sub-criteria for identifying and selecting suitable lands for developing the urban uses in Bandar Abbas districts. Thus, an inclusive interview has been conducted with 20 experts including university scholars in fields of geography, environment, economy, social science, civil engineering, architecture and urbanism as well as the director of the administrative section and developing the private construction company, professional consultants and seasoned experts of the state administrative organizations for evaluating the suitable criteria of the urban development and specifying the maximum suitable replaced locations. Finally, 10 potential locations for choosing the most suitable lands are determined according to results obtained by Fuzzy AHP analysis model illustrated in **Fig. 6**. The potential regions include the districts: Amir Abad, Azad Shahr, Damai, Golshahr Jonobi, Hormozan, Khaje Ata, Koye Farhangiyan, Panzdah Khordad, Shahrak Imam Reza and Ziba Shahr.

Amir Abad because of its open lands and newly-established feature and also vicinity to the residential town of navy has a high capability for administering the urban development plans. Azad Shahr region has a good potential for development owing to its compliance to construction density and urbanization standards. Damai district has had a balanced growth during the recent years, due to vicinity to the greatest university center of Bandar Abbas city and the residential lands of Tavanir town. Among the other advantages of this district, one can refer to complying with capitations in urban planning. Golshahr Jonobi is the widest region among the potential regions for urban development. This region is located in the southern margin next to the state coastal park. This park is the largest urban park of Bandar Abbas and has the multi-functional recreational, sport and commercial potentialities. The region of Hormozan is located in neighborhood of the greatest remedial center of Hormozgan province (Bandar Abbas city). One of the development advantages of this region is observation of per-capita and construction density. Khaje Ata district has command over the seacoast, open lands and suitable availabilities and so it has very appropriate advantage for urban development. The greatest green space complex, commercial collection and congregation saloon are located in the district of Koye Farhangiyan; its built-in urban uses are based on the urbanization principles; meanwhile, lack of open lands has caused restrictions for this region's development. The greatest residential hotel of the city (five-star hotel of Hormoz) and Takhti sport complex are located in Panzdah Khordad region. The other advantages of this region include the neighborhood of the south boundary of this region to seasonal river of Shahnaz (considered as a suitable element in the urban planning) and having open spaces. Shahrak Imam-Reza is one of the newly-established regions located in the north of Bandar Abbas city. It has very suitable availabilities and open spaces. Ziba Shahr region has a relatively high antiquity. However, because of sticking to the urbanization principles and observing capitations and urban density in its construction, it has an appropriate potential for establishing and developing the urban uses. The potential locations are shown in **Fig. 14.** Furthermore, an accurate questionnaire has been provided based on the collected data and according to the quantitative and qualitative criteria for choosing the suitable model. A lot of face-to-face interviews have been then conducted for obtaining the database and

Table 2. Criteria, sub-criteria and source of geospatial data used in this study

Main criteria	Sub-criteria	Source	Year
Cultural and Historic	Aesthetics	Master plan	2006
	Cultural and Tourism	Master plan	2006
	Historical places	Master plan	2006
	Local built environment	Master plan	2006
Ecological and Environmental	Coastal line	Geo-Eye Image Satellite	2012
	Green space	Geo-Eye Image Satellite	2012
	Noise pollution	Iran department of environment	2012
	Wastewater network	Regional water company	2012
	Water pollution	Iran department of environment	2012
Physical	Aspect	Topographic map (1:500)	2001
	Digital Elevation Model	Topographic map (1:500)	2001
	Fault	Geology map (Scale 1:50000)	2010
	Geology	Geology map (Scale 1:50000)	2010
	Hydrology	Topographic map (Scale 1:500)	2001
	Slope	Topographic map (Scale 1:500)	2001
	Soil	Soil map (Scale 1:50000)	2008
Economic	Commercial center	Master plan	2006
	Commercial and fishing ports	Ports and maritime organization	2012
	Land value	Bandar Abbas municipality	2012
Social	Administrative center	Master plan	2006
	Distribution of population	Iranian Statistic Center	2012
	Education center	Master plan	2006
	Household size	Iranian Statistic Center	2012
	Medical center	Master plan	2006
	Neighborhood community change	Master plan	2006
	Population density	Iranian Statistic Center	2012
Structural	Construction density	Master plan	2006
	Construction pattern	Master plan	2006
	Functional zoning	Master plan	2006
	Height building	Aerial photo – Ultra Cam D	2012
	Land area	Master plan	2006
	Land use	Master plan	2006
	Lifetime	Master plan	2006
	Road network	Master plan	2006
	Total residential density	Master plan	2006
Accessibility	Airport, Railway and Port for passenger	Road and Urban Development Organization	2010
	Bus way	Bandar Abbas municipality	2012
	Bus station	Bandar Abbas municipality	2012
	Fire station and hydrant	Fire department	2012
	Line communication	Telecommunication Co.	2012
	Post office	Post Co.	2012
	Power distribution network	Hormozgan Electrical Distribution Co.	2012
	Road network	Master plan	2006
	Water zone area	Regional Water Co.	2012

expanding it according to the selected criteria. In order to recognize the criteria for selection, a number of quantitative and qualitative parameters influencing the process of location evaluating should be regarded. Here, an extensive and complicated table exists on the evaluation criteria based on the previously-mentioned sources. After consulting with above-mentioned experts and through their guidance, seven specified criteria along with 44 layers of information were determined for doing the analysis (**Table 2**).

Seven criteria investigated in this research include: cultural and historical, environmental and ecological, economic, social, physical, structural and accessibility represented by C_1, C_2, C_3, C_4, C_5, C_6 and C_7, respectively. Cultural and historical criterion involves the ancient buildings which illustrate the historical identity of a region over time and also culture and customs of these regions' inhabitants over the course of time. The indices of the cultural-historical criterion are based on aesthetic standards, historical places and tourist regions. Balance in growth and development along with environmental concerns plays a key role in the developing and metropolis cities. Environmental and ecological criterion involves the effective factors on the changes in life quality and environment of the region of study. In Bandar Abbas city, coastline is the major factor in evaluating this criterion. Pollutant sources (weather, soil and water), green space capitation and sewage disposal system are among other factors for environmental conditions of the region. The physical condition of the cities is one of the factors influencing the cities' formation process. Physical criterion includes factors such as digital elevation model (DEM), slope, geology, soil type and the status of territorial surface waters. Bandar Abbas city due to its coastal nature has sprawled in course of time along the coast in form of a line. A major part of the city is located in low elevation and in a very low slope; as we move to the north of the city, the elevation increases and consequently the land's slope becomes sharper, too. Other factors such as soil stiffness and soil type are also effective in the process of urban construction and building strength.

The analysis of gross population density and its necessary capitations is proposed as a necessity in the urban planning and administration. So, within social criterion, issues like changes in the neighbor communities in course of time, capitation and availability of the administrative, educational and remedial centers have been investigated. Economic growth and urban growth are interrelated from different aspects and increased economic growth in urban communities and providing the budget for governmental organizations and urban centers, naturally leads to implementing executive plans and development projects toward urban development. Furthermore, the urban economic growth also increases the participation of the private investors and governmental organizations in urban development projects. In this line, in the present study, data related to the commercial centers, the ports of exporting and importing products and land's cost have been used for analyzing the economic criterion. The structural criterion is one of the most effective criteria in studying and identifying the suitable lands for urban development. In this criterion, factors such as lands' uses, functional zone, residential density, construction density, construction model, the height and the antiquity of the building and the amount of open urban spaces are dealt with. Among the mentioned factors, lands' use, the indices of density and the amount of open spaces are among the main advantages determining the suitable regions for urban development in structural criterion. The city of Bandar Abbas has undergone unsystematic and unbalanced growth in course of its formation process. Therefore, the incompatible uses and limitation of lands in the old areas of the city are regarded as restrictions to the urban development. In most of the regions with developed area, the allocation of uses' capitation according to the master plan has been complied. The presence of open lands in the developed area makes the balanced growth and development possible in such regions.

The criterion of accessibility in the present study is the distance from the urban infrastructures including road system, power network lines, communication lines, water distribution network, postal centers, fire-fighting stations and the centers of traveler and product transportation (bus stop, railroad, passenger ports and airport). For the master plan of Bandar Abbas city not being fully conducted and also its unsystematic development in some of north, northeast and northwest parts, the urban infrastructures have not transferred fully and this has made some troubles for the inhabitants of the city. In the old areas of the city, neglecting the urban infrastructures in course of time has caused that the existent accessibilities lack acceptable qualities for the inhabitants of these regions.

RESULT AND SENSITIVITY ANALYSIS

In the first step of the research, we use AHP and Fuzzy AHP models for determining the priorities and importance of the research criteria. After extracting the final map based on the degree of importance according to the land's development potential, we classify the output results (**Figs. 5–6**). Prioritizing classes have been

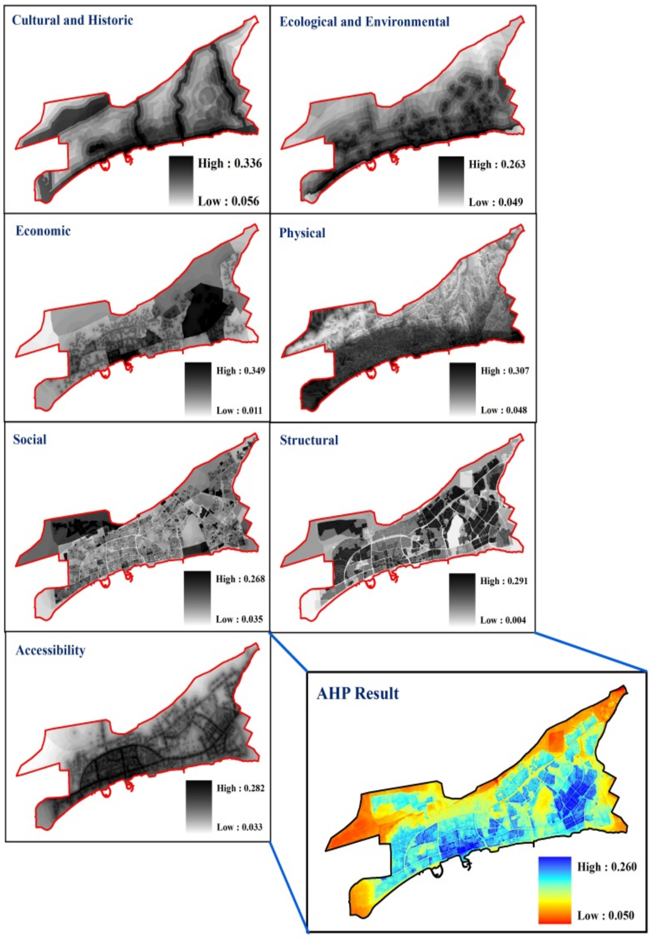


Fig. 5 Prioritize the development of urban lands by using AHP model.

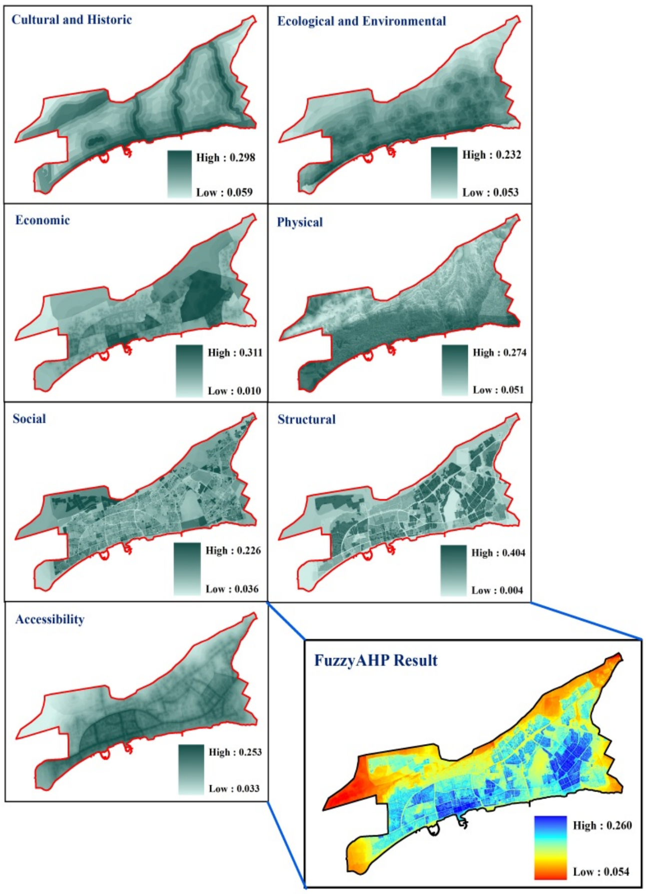


Fig. 6 Prioritize the development of urban lands by using Fuzzy AHP model.

classified on the basis of very high suitable, high suitable, suitable, moderate, unsuitable, high unsuitable and very high unsuitable. According to the obtained results, shown in **Fig. 7**, the South to the center of the city, East and Northeast regions has the highest amounts of the suitable lands for urban development.

Figure 8 illustrates the highest percentage of urban lands area according to AHP model belongs to the moderate class (19.36%) and the lowest percentage of area belongs to the class of very high suitable (3.62%). In the next stage, based on Fuzzy AHP model we normalize the results obtained from AHP model; according to the results shown in **Fig. 9**, the suitable lands identified in the previous stage are definitely clear and the degree of importance is specified. According to results shown in **Fig. 10**, the South and East regions and some Northeast parts have the highest amount of suitable lands for urban development. We follow the process of classifying Fuzzy AHP results as the previous stage and as it is clear in **Fig. 10**, the highest percentage of urban lands area based on Fuzzy AHP belongs to the middle class (23.10%) and the lowest percentage of area belongs to the very high suitable class (2.94%).

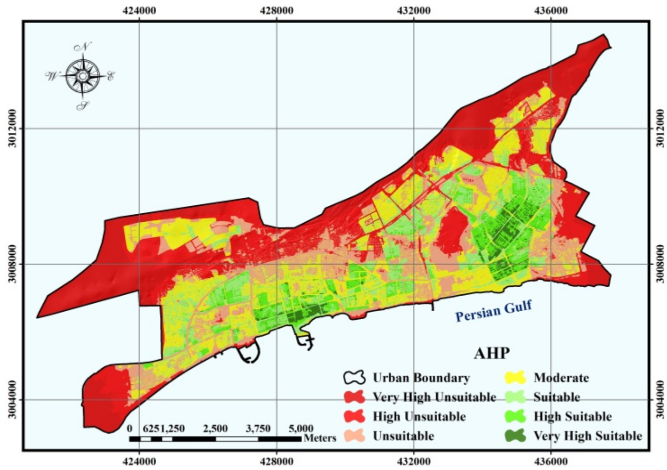


Fig. 7 Classification results for the AHP model.

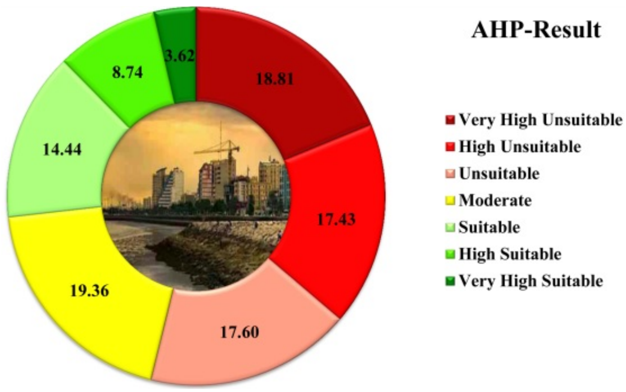


Fig. 8 Percentage of the land area for urban development (AHP).

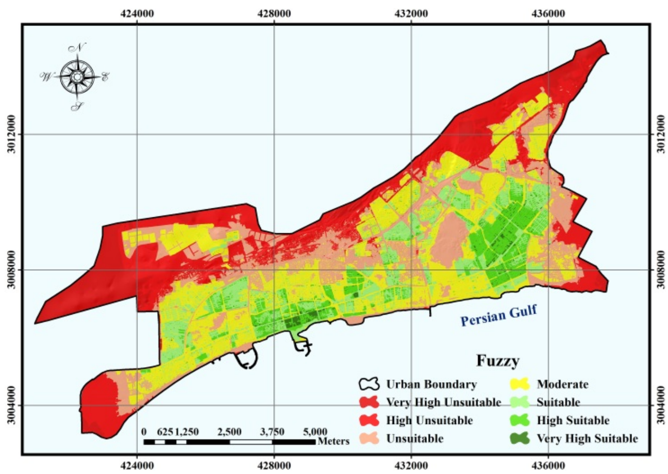


Fig. 9 Classification results for the Fuzzy AHP model.

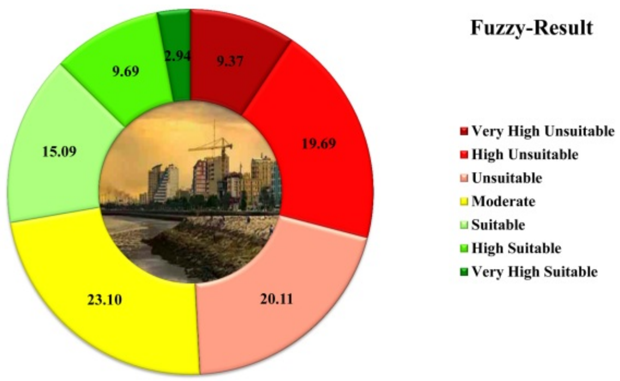


Fig. 10 Percentage of the land area for urban development (Fuzzy AHP).

For validating the research results of AHP and Fuzzy AHP models and also determining the best output of these models, we did a field observation and sampling of 1300 points (**Fig. 11**) in the city of Bandar Abbas based on the obtained results.

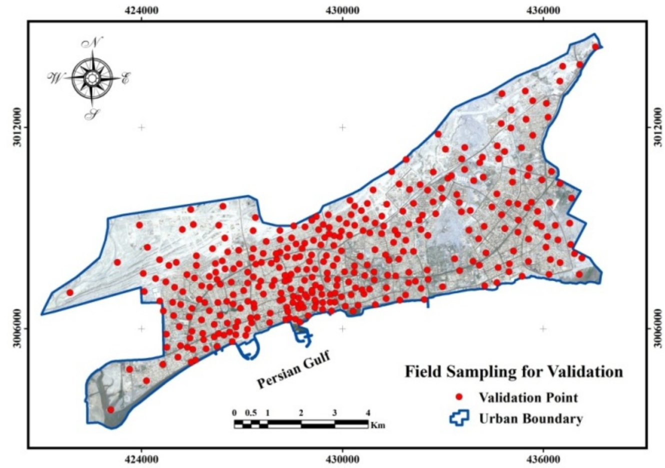
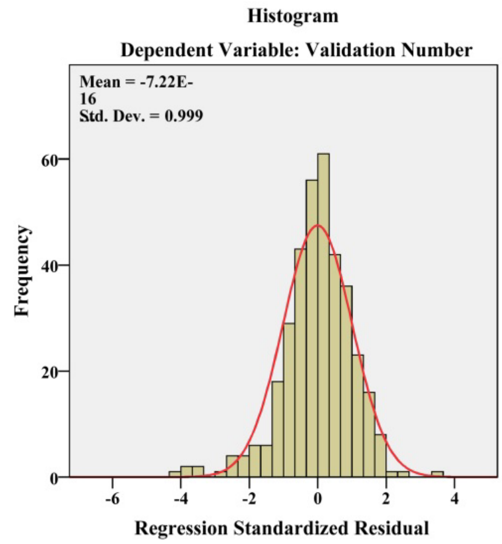
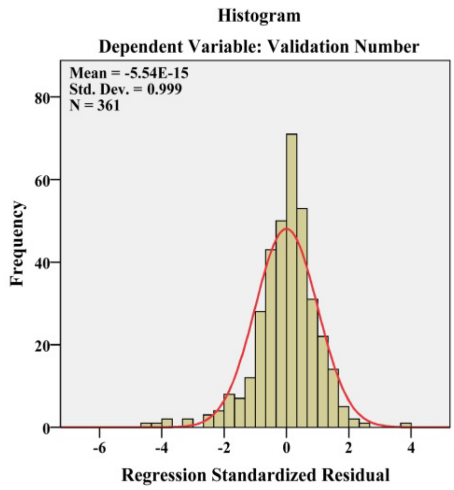


Fig. 11 Field sampling for validation.

In the third step of the analysis, based on the collected points and determining the numerical value of each point using linear regression model, we determined the best model for identifying lands suitable urban development in the districts of Bandar Abbas city. At first, after standardizing the weights to be analyzed (**Figs. 12–13**), we tested the linear regression model for the results obtained from AHP and Fuzzy AHP based on the sampled points. As it is clear from **Figs. 12–13**, Fuzzy AHP model with R^2=0.822 has a higher significance level than AHP model with R^2=0.814 and so it is determined as the final model of analysis for identifying the suitable lands for urban development in Bandar Abbas. Next, among the districts located in the lands suitable for the city development, those districts have been selected which have the highest percentage of the development potential area. As show in **Fig. 14**, Amir Abad (L_1), Azad Shahr (L_2), Damai (L_3), Golshahr Jonobi (L_4), Hormozan (L_5), Khaje Ata (L_6), Koye Farhangian (L_7), Panzdah Khordad (L_8), Shahrak Imam Reza (L_9) and Ziba Shahr (L_{10}) have been selected as the districts with highest potential of urban development. The analysis continues with choosing the priorities in the selected districts through using Fuzzy TOPSIS model, according to the significance level of the research criteria.





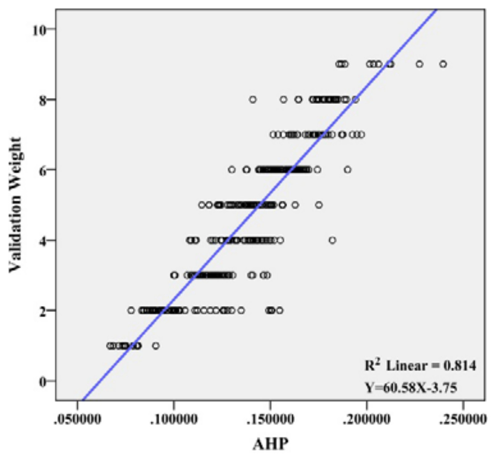


Fig. 12 Standardization and correlation diagram of AHP model.

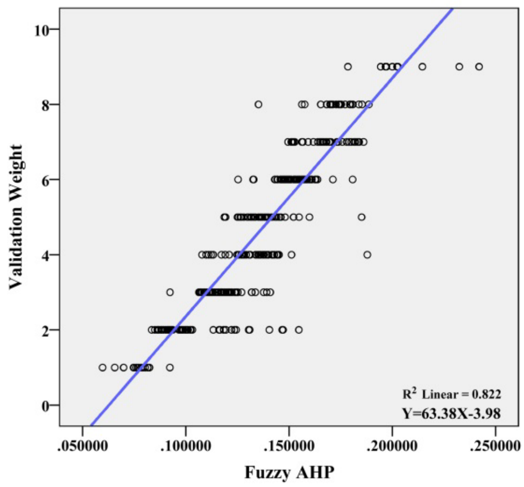


Fig. 13 Standardization and correlation diagram of Fuzzy AHP model.

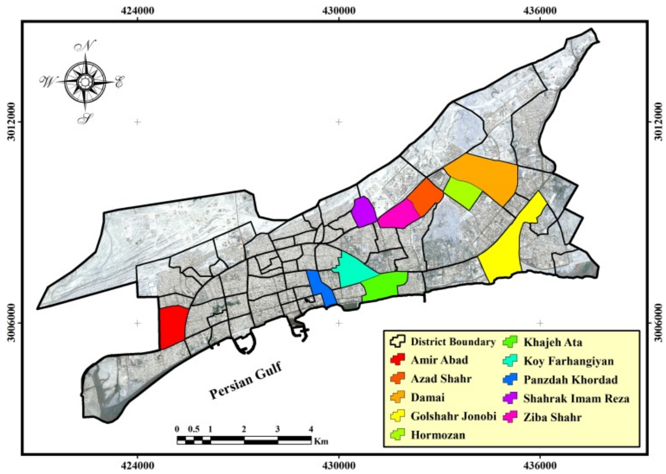


Fig. 14 The potential location of appropriate lands for urban development.

In this section of the research, to undertake the ambiguities that exist in the linguistic valuation of the data as a process, TFNs is used to perform pairwise comparisons. The above mentioned questionnaire was used again for doing face-to-face interviews with the experts so that the pairwise comparisons are performed. Specifying the importance weights of the criteria is the aim of utilizing Fuzzy AHP that will be used in Fuzzy TOPSIS method. **Table 4** illustrates the pairwise comparison matrix which was set by TFNs which ties to linguistic statements of data. To crisp values through the Chang's extent analysis stated previously, the fuzzy values of paired comparison were transformed. First, the fuzzy synthetic extent values were computed by using **Eq. (8)** with the help of **Eqs. (9)-(11)**. **Eqs. (12), (13)** and **(14)** were used to reflect the degree of synthetic extent values. To have a weight vector, as given by **Eq. (16), Eqs. (14)** and **(15)** were implemented through making comparison between the fuzzy numbers. As defined in **Eq. (17)**, after the weight vector is normalized the created priority weight vector of criteria is illustrated in **Table 4**. As shown in **Table 4**, 'structural' and 'accessibility criteria are considered the most significant two criteria influencing the process of selection in land development. In decision matrix the importance degree relevant to the criteria is described through the preference weight vector. Following attaining the importance degree of criteria, it was through Fuzzy TOPSIS method that alternative locations were evaluated. It is at this point of the research when establishing fuzzy assessments of the alternative locations (L_D1, L_D2, L_D3, L_D4, L_D5, L_D6, L_D7, L_D8, L_D9 and L_D10) is begun by Fuzzy TOPSIS based on the criteria through reusing TFNs. The result is decision matrix for ranking alternatives which mirrors the efficiency ratings of the alternatives concerning the criteria. The linguistic scales and their corresponding fuzzy numbers are used as : (1,1,1)-very poor, (2,3,4)-poor, (4,5,6)-fair, (6,7,8)-good, (8,9,10)-very good. What illustrated in **Table 5** are alternatives compared with regard to criteria. Following the creation of decision matrix, calculation of normalized decision matrix begins. To obtain the normalized decision matrix **Eq. (22)** is used. The third and the fifth criterion are referred to as the coast criteria; other criteria are referred to as the benefit criteria. As a case in point for the benefit criterion $'C_1'$, the maximum value of the criterion is $'C_1'$ fuzzy numbers (8,9,10) on alternative L_D2. The normalization calculation for alternative L_D4 is :

(6,7,8)/(8,9,10) = (6/8, 7/9, 8/10) = 0.75,0.77,0.8.

Further example that can be offered for cost criterion is shown below. The minimum value of the criterion $'C_3'$ is fuzzy numbers (2,3,4) on alternative L_D5. The normalization calculation for alternative L_D8 is:

(2,3,4) / (8,9,10) = (2/8,3/9,4/10) = (0.25,0.33,0.4).

As shown in the table, to attain the weighted normalized fuzzy decision matrix the normalized decision matrix should be multiplied by the weights of the criteria matrix (**Table 4**) found when the Fuzzy AHP is used. Weighted normalized decision matrix is illustrated in **Table 6**.

Table 4. Pairwise comparisons of land selection criteria for urban development via TFN.

	Structural	**Accessibility**	**Economical**	**Social**	**Physical**	**Ecological and Environ.**	**Cultural and Historic**	**Priority Weight (W)**
Structural (F_1)	(1,1,1)	(1,2,3)	(2,3,4)	(2,3,4)	(2,3,4)	(2,3,4)	(3,4,5)	0.2867
Accessibility(F_2)	(0.33, 0.5,1)	(1,1,1)	(1,2,3)	(1,2,3)	(1,2,3)	(1,2,3)	(2,3,4)	0.1886
Economical (F_3)	(0.25,0.33,0.5)	(0.33, 0.5,1)	(1,1,1)	(1,2,3)	(1,2,3)	(1,2,3)	(2,3,4)	0.1635
Social (F_4)	(0.25,0.33,0.5)	(0.33, 0.5,1)	(0.33, 0.5,1)	(1,1,1)	(1,2,3)	(1,2,3)	(1,2,3)	0.1257
Physical (F_5)	(0.25,0.33,0.5)	(0.33, 0.5,1)	(0.33, 0.5,1)	(0.33, 0.5,1)	(1,1,1)	(1,2,3)	(1,2,3)	0.1031
Ecological and Environmental(F_6)	(0.25,0.33,0.5)	(0.33, 0.5,1)	(0.33, 0.5,1)	(0.33, 0.5,1)	(0.33, 0.5,1)	(1,1,1)	(1,2,3)	0.0805
Cultural and History (F_7)	(0.2,0.25,0.33)	(0.25,0.33,0.5)	(0.25,0.33,0.5)	(0.33, 0.5,1)	(0.33, 0.5,1)	(0.33, 0.5,1)	(1,1,1)	0.0515

$V(S_{R_1} \geq S_{R_2}, S_{R_3}, S_{R_4}, S_{R_5}, S_{R_6}, S_{R_7}) = 1.000$ $V(S_{R_2} \geq S_{R_1}, S_{R_3}, S_{R_4}, S_{R_5}, S_{R_6}, S_{R_7}) = 0.714$

$V(S_{R_3} \geq S_{R_1}, S_{R_2}, S_{R_4}, S_{R_5}, S_{R_6}, S_{R_7}) = 0.686$ $V(S_{R_4} \geq S_{R_1}, S_{R_2}, S_{R_3}, S_{R_5}, S_{R_6}, S_{R_7}) = 0.611$

$V(S_{R_5} \geq S_{R_1}, S_{R_2}, S_{R_3}, S_{R_4}, S_{R_6}, S_{R_7}) = 0.508$ $V(S_{R_6} \geq S_{R_1}, S_{R_2}, S_{R_3}, S_{R_4}, S_{R_5}, S_{R_7}) = 0.374$

Table 5. The comparison of alternatives based on criteria.

	L_D1	L_D2	L_D3	L_D4	L_D5	L_D6	L_D7	L_D8	L_D9	L_D10
C1	(8,9,10)	(6,7,8)	(4,5,6)	(6,7,8)	(5,6,7)	(3,4,5)	(4,5,6)	(2,3,4)	(7,8,9)	(7,8,9)
C2	(2,3,4)	(4,5,6)	(4,5,6)	(7,8,9)	(3,4,5)	(5,6,7)	(6,7,8)	(8,9,10)	(3,4,5)	(4,5,6)
C3	(5,6,7)	(4,5,6)	(8,9,10)	(6,7,8)	(8,9,10)	(3,4,5)	(7,8,9)	(2,3,4)	(5,6,7)	(6,7,8)
C4	(4,5,6)	(5,6,7)	(6,7,8)	(8,9,10)	(7,8,9)	(3,4,5)	(7,8,9)	(2,3,4)	(2,3,4)	(4,5,6)
C5	(6,7,8)	(2,3,4)	(4,5,6)	(5,6,7)	(2,3,4)	(8,9,10)	(8,9,10)	(7,8,9)	(2,3,4)	(2,3,4)
C6	(5,6,7)	(4,5,6)	(5,6,7)	(6,7,8)	(6,7,8)	(7,8,9)	(7,8,9)	(8,9,10)	(2,3,4)	(3,4,5)
C7	(2,3,4)	(4,5,6)	(3,4,5)	(7,8,9)	(2,3,4)	(7,8,9)	(6,7,8)	(8,9,10)	(3,4,5)	(5,6,7)

Table 6. Weighted normalized decision matrix.

	L_D1	L_D2	L_D3	L_D4	L_D5
C1	(1,1,1)	(0.75,0.77,0.8)	(0.5,0.55,0.6)	(0.75,0.77,0.8)	(0.62,0.66,0.7)
C2	(0.25,0.33,0.4)	(0.5,0.55,0.6)	(0.5,0.55,0.6)	(0.87,0.88,0.9)	(0.37,0.44,0.5)
C3	(0.62,0.66,0.7)	(0.5,0.55,0.6)	(1,1,1)	(0.75,0.77,0.8)	(1,1,1)
C4	(0.5,0.55,0.6)	(0.62,0.66,0.7)	(0.75,0.77,0.8)	(1,1,1)	(0.87,0.88,0.9)
C5	(0.75,0.77,0.8)	(0.25,0.33,0.4)	(0.5,0.55,0.6)	(0.62,0.66,0.7)	(0.25,0.33,0.4)
C6	(0.62,0.66,0.7)	(0.5,0.55,0.6)	(0.62,0.66,0.7)	(0.75,0.77,0.8)	(0.75,0.77,0.8)
C7	(0.25,0.33,0.4)	(0.5,0.55,0.6)	(0.37,0.44,0.5)	(0.87,0.88,0.9)	(0.25,0.33,0.4)

	L_D6	L_D7	L_D8	L_D9	L_D10
C1	(0.37,0.44,0.5)	(0.5,0.55,0.6)	(0.25,0.33,0.4)	(0.87,0.88,0.9)	(0.87,0.88,0.9)
C2	(0.62,0.66,0.7)	(0.75,0.77,0.8)	(1,1,1)	(0.37,0.44,0.5)	(0.5,0.55,0.6)
C3	(0.37,0.44,0.5)	(0.87,0.88,0.9)	(0.25,0.33,0.4)	(0.62,0.66,0.7)	(0.75,0.77,0.8)
C4	(0.37,0.44,0.5)	(0.87,0.88,0.9)	(0.25,0.33,0.4)	(0.25,0.33,0.4)	(0.5,0.55,0.6)
C5	(1,1,1)	(1,1,1)	(0.87,0.88,0.9)	(0.25,0.33,0.4)	(0.25,0.33,0.4)
C6	(0.87,0.88,0.9)	(0.87,0.88,0.9)	(1,1,1)	(0.25,0.33,0.4)	(0.37,0.44,0.5)
C7	(0.87,0.88,0.9)	(0.75,0.77,0.8)	(1,1,1)	(0.37,0.44,0.5)	(0.62,0.66,0.7)

Using the weighted normalized values can determine the negative ideal solutions (A^{-}) and positive ideal solution (A^{*}). Moreover, for determining the positive and negative ideal solutions **Eqs. (23)** and **(24)** are utilized. The positive TFNs are in the range [0, 1]. Therefore, the fuzzy positive ideal reference point ($FPIS, A^{*}$) is (1,1,1) and fuzzy negative ideal reference point ($FNIS, A^{-}$) is (0,0,0). The final phase is calculation of the relative closeness to the ideal solution. **Eqs. (25)** and **(26)** depict the relative closeness to the ideal scenario. Through Eq. **(18)**, distance to ideal solutions is calculated. **Table 7** sums up the final results. Higher the closeness equals to the better rank, so the relative closeness to the ideal solution of the alternatives can be replaced as follows: $CC_6 > CC_8 > CC_9 > CC_3 > CC_2 > CC_5 > CC_{10} > CC_1 > CC_7 > CC_4$. L_D6 is specified as the best location alternative.

Table 7. Fuzzy TOPSIS results.

Alternatives	D_j^{*}	D_j^{-}	CC_j
L_D1	0.075	0.089	0.4573
L_D2	0.072	0.064	0.5316
L_D3	0.075	0.066	0.5318
L_D4	0.038	0.094	0.2862
L_D5	0.076	0.073	0.5100
L_D6	0.090	0.054	0.6269
L_D7	0.059	0.081	0.4205
L_D8	0.102	0.073	0.5808
L_D9	0.082	0.072	0.5322
L_D10	0.066	0.078	0.4585

A sensitivity analysis was also implemented to achieving the accuracy of the final results. The notion of sensitivity analysis is replacing different criterion's weights take the place of one another, and the result is forming 21 different calculations. For every calculation we tend to find CC^{*}values and diverse names are offered for every calculation. A case in point is CC_{13}^{*} which means the weights of criterion 1 and also criterion 3 have altered and CC_{45}^{*} shows a change in criterion 4's and criterion 5's weights.

Figure 16 summarizes new CC^{*} values of the alternatives on graph. Also **Table 8** illustrates new CC^{*} values. It is obvious from **Fig.16** and **Table 8**, L_D6 is also the best alternative in the 4th, 5th, 6th, 11th, 11th, 14th, 15th, and 21nd calculations. The best alternative in the rest of the calculations is L_D8. Based on criteria importance decision maker can choose one of them.

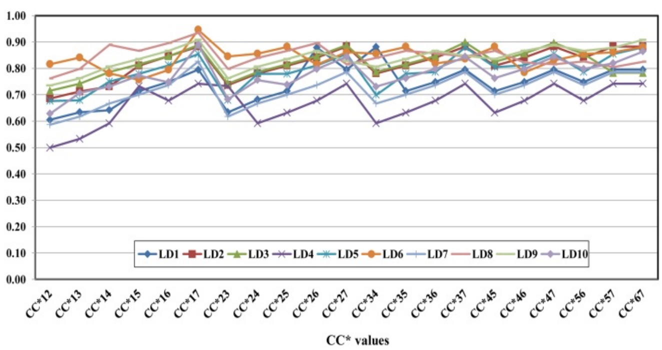


Fig. 15 New CC^{*} value of the alternatives

Table 8. The sensitivity analysis result.

	L_D	L_D	L_D	L_D	L_D	L_D	L_D	L_D	L_D	L_D1
CC^*_{12}	0.6	0.6	0.7	0.5	0.6	0.8	0.5	0.7	0.7	0.63
CC^*_{13}	0.6	0.7	0.7	0.5	0.6	0.8	0.6	0.8	0.7	0.71
CC^*_{14}	0.6	0.7	0.7	0.5	0.7	0.7	0.6	0.8	0.8	0.73
CC^*_{15}	0.7	0.8	0.8	0.7	0.7	0.7	0.7	0.8	0.8	0.77
CC^*_{16}	0.7	0.8	0.8	0.6	0.8	0.7	0.7	0.9	0.8	0.75
CC^*_{17}	0.8	0.8	0.8	0.7	0.8	0.9	0.8	0.9	0.9	0.89
CC^*_{23}	0.6	0.7	0.7	0.7	0.6	0.8	0.6	0.8	0.7	0.68
CC^*_{24}	0.6	0.7	0.7	0.5	0.7	0.8	0.6	0.8	0.8	0.76
CC^*_{25}	0.7	0.8	0.8	0.6	0.7	0.8	0.7	0.8	0.8	0.74
CC^*_{26}	0.8	0.8	0.8	0.6	0.8	0.8	0.7	0.9	0.8	0.80
CC^*_{27}	0.8	0.8	0.8	0.7	0.8	0.8	0.7	0.8	0.8	0.84
CC^*_{34}	0.8	0.7	0.7	0.5	0.7	0.8	0.6	0.8	0.8	0.73
CC^*_{35}	0.7	0.8	0.8	0.6	0.7	0.8	0.7	0.8	0.8	0.76
CC^*_{36}	0.7	0.8	0.8	0.6	0.7	0.8	0.7	0.8	0.8	0.80
CC^*_{37}	0.8	0.8	0.9	0.7	0.8	0.8	0.7	0.8	0.8	0.84
CC^*_{45}	0.7	0.8	0.8	0.6	0.8	0.8	0.7	0.8	0.8	0.76
CC^*_{46}	0.7	0.8	0.8	0.6	0.8	0.7	0.7	0.8	0.8	0.80
CC^*_{47}	0.8	0.8	0.9	0.7	0.8	0.8	0.7	0.8	0.8	0.84
CC^*_{56}	0.7	0.8	0.8	0.6	0.7	0.8	0.7	0.8	0.8	0.80
CC^*_{57}	0.8	0.8	0.7	0.7	0.8	0.8	0.7	0.8	0.8	0.82
CC^*_{67}	0.8	0.8	0.7	0.7	0.8	0.8	0.7	0.8	0.9	0.86

CONCLUSION

Population growth, political stability and economic growth have caused the cities to grow and to develop, and the suitable lands for development in cities are considered as one of the requirements of development. Thus, identification of lands suitable for development, especially in the urban regions for governmental institutions (for implementation of development projects), state and private investors is a challenging task. In the current research, the combined approach to Fuzzy MCDM method based on Fuzzy TOPSIS and Fuzzy AHP models is proposed in order to find the suitable lands for urban development. The study carried out in Bandar Abbas city has been conducted as the explanation for the combined model on the basis of seven real-world criteria. In the used methods, the Fuzzy AHP model was first employed to determine the weights of criteria and sub-criteria and then Fuzzy TOPSIS model was made use of for ranking the identified alternative locations. In fact, this article has dealt with the fuzzy decision making in which some data is indefinite in the process. The method which causes the main aspects of TOPSIS and AHP techniques to be combined is the fuzzy environments. As a very beneficial method AHP is used to compare criteria with sub-criteria. TOPSIS is also known as a method to achieve the satisfying (compatible) solutions for multi-criteria problems. It should be noted that as the number of research criteria increases, the precision and quality of alternative locations identification (suitable lands for urban development) are also enhanced. According to the results obtained in this study, the presented methods in fact constitute a process for ranking the alternative locations obtained, for recognizing the problems of large scales.

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