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A Courthouse site selection method using hesitant fuzzy linguistic term set: a case study for Turkey

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Abstract

The selection of location is generally one of the utmost significant and considered decision for future success of a courthouse building. However, site selection is an important decision and is influenced by numerous causes both quantitative and qualitative for a courthouse, yet the topic is not studied academically in Turkey. As a first study in its field in Turkey, there were no previously established criteria set for courthouse site evaluation, accordingly, the US courthouse site selection documents are handled as the most improved and available decision set for selection criteria. These criteria are adapted by an expert group for Turkish circumstances mainly under 6 headings. The key criteria taken into account in this study are, 1-required site area/site coverage, 2-site location adjacencies, 3-traffic and transportation, 4-site acquisition cost, 5-environmental impact and sustainability, 6-physical elements such as topography and hydrology. Under these main criteria some additional sub-criteria are also included because of the structure of the problem. Since these criteria tend to be inexact or ambiguous nature of the linguistic assessment of courthouse location selection problem, hesitant fuzzy approach is applied to gauge the weightings of these criteria. Then, courthouse location weighting model is established and a case study is applied with the officials of the Turkish Ministry of Justice for a newly planned courthouse in Ankara, Turkey for site selection decision. This paper demonstrates an application of hesitant multi-criteria fuzzy logic to an actual courthouse location selection problem.

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1. Introduction

Courthouses are one of the most significant civic buildings of a cityscape since they fulfil important functions in city life in Turkey. These buildings not only do assist essential missions, but they also contributes the formation of communal spaces. The courthouses in Turkey tend to be respected as national landmarks and a well-designed courthouse will definitely pay off its initial cost by improving environmental quality in cities. Similar to other big construction activities, location selection decision has an intense influence on practically all aspects of the design process of a courthouse project. The location of the building affects its functionality; operational efficiency; security and additional potentials of the facility since the decision directly influences the balance between the initial cost of the building, and the overall cost of the project. It is evident that the decision is highly important while achieving value for the environment and the city. While the initial cost may be a substantial motivator in Turkish case, all aspects must be considered in order to make the right decision within this process.

In this paper, a site selection criteria weighting method to evaluate the Courthouse site selection problem is addressed for Turkey. Since there were no previously established criteria for Turkey, the US courthouse site selection documents are handled as the most improved and available decision set for selection criteria[1]. The proposed criteria is based on the criteria set for the U.S. General Services Administration (GSA) suggests for similar purposes. However the criteria set is adjusted by an expert group of courthouse buildings for the Turkish case. Accordingly these criteria are adapted for Turkish circumstances mainly under 6 headings. The main criteria taken into account according to this study are, 1-required site area/site coverage, 2-site location adjacencies, 3-traffic and transportation, 4-site acquisition cost, 5-environmental Impact and sustainability, 6-physical elements (topography and hydrology). Under these main criteria and some additional sub-criteria are also included because of the structure of the problem. Later an expert group who are the members of Courthouse Buildings Technical Commission of Ministry of Justice of Turkey is evaluated the criteria from their point of view by using Hesitant Fuzzy Linguistic Term Set (HFLTS).

As in most types of the selection problems, any of the multi criteria decision making methods (MCDM) can be employed to solve this complicate decision problem. However, since in this topic decision maker could not decide superiorities of alternatives and criteria, using classical multi criteria decision making methods may not be consistent. In existing literature, site selection problem is handled with several MCDM methods. To illustrate, Hacioglu et al[2] selected appropriate locations for two air quality monitoring stations in an urban area in Turkey by using specific decision-making techniques. In their study AHP (Analytic Hierarchy Process) and ELECTRE (Elemination and Choice Translating Reality English) methods are employed. As another case in point, Erol et al[3] investigated a fuzzy MCDM context for pinpointing a nuclear power plant in Turkey. These researchers' tool that is used for the problem is based on 'fuzzy entropy' and 't norm based fuzzy compromise programming' to consider the ambiguity of human decisions. As a third example, Liu et al[4] used 'VIKOR'(Vise Kriterijumska Optimizacija I Kompromisno Resenje) method under fuzzy environment for site selection problem. However, there is no study exist currently which used HFLTS for deciphering site selection problem in literature. Since, an expert or decision maker may hesitate between different linguistic terms, they require richer expressions to fully express their knowledge, and by this means hesitant fuzzy linguistic model can be seen as a good alternative to evaluate such conditions. Hesitant Fuzzy Linguistic Term Set (HFLTS) permit decision makers to express their knowledge more properly and it is employed to increase profusion of linguistic excerpt grounded on the fuzzy linguistic approach. In this paper, the weightings of courthouse location selection criteria is congregated through an expert group survey study grounded on Hesitant Fuzzy Linguistic Term Set (HFLTS) and as a result, courthouse location selection criteria weighting is attained. The paper is organized as follows; after the introduction, in the second part steps of HFLTS algorithm in decision making is given, in the third part courthouse site selection problem using HFLTS is explained, and in the last part results of the study are discussed.

2. Steps of Algorithm of HFLTS in decision making

Decision making has been studied by using various multi-criteria decision making methods. Nonetheless, decision maker may hesitate between criteria, or alternatives about which is better. To use a richer expression to express the experts' knowledge, HFLTS is one of the best methods that has the potential. In recent years, there has

been an increasing interest in Hesitant Fuzzy Linguistic Term Set while some research has been carried out on this topic, there have been few empirical investigations about it. Since HFLTS is a fairly novel method there are few examples exist in literature. To illustrate some examples, Rodriguez et al. introduced hesitant fuzzy linguistic term set by using comparative terms to offer a linguistic and computational basis to increase the linguistic excerpt based on the use of context-free grammars and fuzzy linguistic approach[5,6]. Nevertheless, decision maker may hesitate between criteria, or alternatives about which is better than the other one. For this reason, HFLTS which is used for richer expression to express expert's knowledge, can be preferred in decision making area. To demonstrate, Zhang and Wu studied relationship between hesitant fuzzy linguistic aggregation operators[7]. While some researchers has been carried research on this topic, there have been few empirical investigations about related topics. To exemplify, Yavuz et al used HFLTS to select fuel vehicles[6]. Liu, H. and Rodríguez presented a new representation of the hesitant fuzzy linguistic term sets by means of a fuzzy envelope to perform the computing with words processes[8]. HFLTS and TOPSIS method used with together in[9] for prioritization of urban transformation projects for Istanbul. Fahmi et al.[10] used together ELECTRE I and HFLTS to solve supplier selection problem. Liao et al.[11] developed a hesitant fuzzy linguistic VIKOR (HFL-VIKOR) technique, encouraged by the VIKOR method and HFL-VIKOR method and steps of algorithm proposed by them[11]. These steps are taken from Yavuz et al.[6]:

"Let the number of any criterion be represented by; $z \in \{1, 2, ..., \tau\}$

Step 1: Define the semantics and syntax of the linguistic term set S. S has following element:
"No importance (ni), very low importance(vli), low importance(li), medium importance(mi), high importance(hi), very high(vhi), absolute importance(ai)"

Step 2: Define the context free grammar G_H, where GH = $\{V_N, V_T, I, P\}$.

$V_N = \{\langle primary\ term\rangle, \langle compozite\ term\rangle, \langle unary\ relation\rangle, \langle binary\ relation\rangle, \langle conjuction\rangle\}$

V_T = {lower than, greater than, at least, at most, between, and, $S_0, S_1 \ldots S_g$}

$I \in V_N$

For the context free grammar, the production rules are as follows:

$$P = \begin{pmatrix} I = \langle \text{primary term} \rangle \,|\, \langle \text{composite term} \rangle, \\ \langle \text{composite term} \rangle ::= \\ \langle \text{unary relation} \rangle \langle \text{primary term} \rangle | \langle \text{binary relation} \rangle \\ \langle \text{primary term} \rangle | \langle \text{conjuction} \rangle \langle \text{primary term} \rangle, \\ \text{primary term} ::= S_0 \,|\, S_1 \,|\, ... \,|\, S_g, \langle \text{unary relation} \rangle ::= \\ \text{lower than} \,|\, \text{greater than} \,|\, \text{at least} \,|\, \text{at most}, \\ \langle \text{binary relation} \rangle ::= \text{between}, \langle \text{conjuction} \rangle ::= \text{and} \end{pmatrix}$$

Step 3: Gather the preferences relations p^k provided by experts, $k \in \{1, 2 \ldots m\}$ for both criteria and alternatives

Step 4: Transform the preferences relations into HFLTS by using the transformation function E_{GH}.

Step 5: Obtain envelope $[p_{ij}{}^{k-}, p_{ij}{}^{k+}]$ for each HFLTS.

Step 6: Select a linguistic aggregation operator φ. Obtain the pessimistic and optimistic collective preference relations P_C^- and P_C^+ by using the linguistic aggregation operator φ. In this paper, arithmetic mean is used for the linguistic aggregation operator[12:]

$$\tilde{x} = \Delta\left(\frac{1}{n}\sum_{i=1}^{n}\Delta^{-1}(s_i, \alpha_i)\right) = \Delta\left(\frac{1}{n}\sum_{i=1}^{n}\beta_i\right) \quad (1)$$

The 2-tuple set associated with S is defined as

S = S * [0.5, 0.5]. The function Δ : [0, g]⟶ S is given by

$$\Delta(\beta) = (s_i, \alpha_i) \text{ with } \begin{pmatrix} i = round(\beta) \\ \alpha = \beta - i \end{pmatrix} \quad (2)$$

Where the round assigns to β the integer number $i \in \{0, 1 \ldots g\}$ closest to β and Δ : [0, g]⟶S is defined by

$$\Delta^{-1}(s_i, \alpha_i) = i + \alpha \quad (3)$$

Step 7.Compute pessimistic and optimistic collective preference for each alternative by linguistic aggregation operator φ.
Step 8. Build a vector of intervals $V^R = \{P_1^R, P_2^R, \ldots\ldots\ldots, P_n^R\}$ of collective preference for the alternatives $P_i^R = [Pi^-, P_i^+]$
Step 9. Normalize the obtained interval utilizes.
Step 10. Calculate the weighted scores, rank the set of alternatives and select the best one.

3. Application of HFLTS method in courthouse site selection criteria weighting

In this section, how multi-criteria HFLTS decision making method on courthouse site selection criteria weighting problem is handled is explained for a new courthouse building decision in Ankara, Turkey. First step of the duty is the development of hierarchic decision model. Since there were no previously established criteria for Turkey related the courthouse site selection criteria, the US courthouse site selection documents are picked up as the most improved and available decision set for selection criteria. Later, these criteria are adapted by an expert group for Turkish circumstances mainly under 6 headings. In Fig.1 decision model are given. Accordingly, the main criteria taken into account in this study are, required site area/site coverage (C1), site location adjacencies (C2), traffic and transportation (C3), site acquisition cost (C4), environmental impact and sustainability (C5), physical elements (topography and hydrology) (C6). Under these main criteria some additional sub-criteria can be seen in In Fig.1.

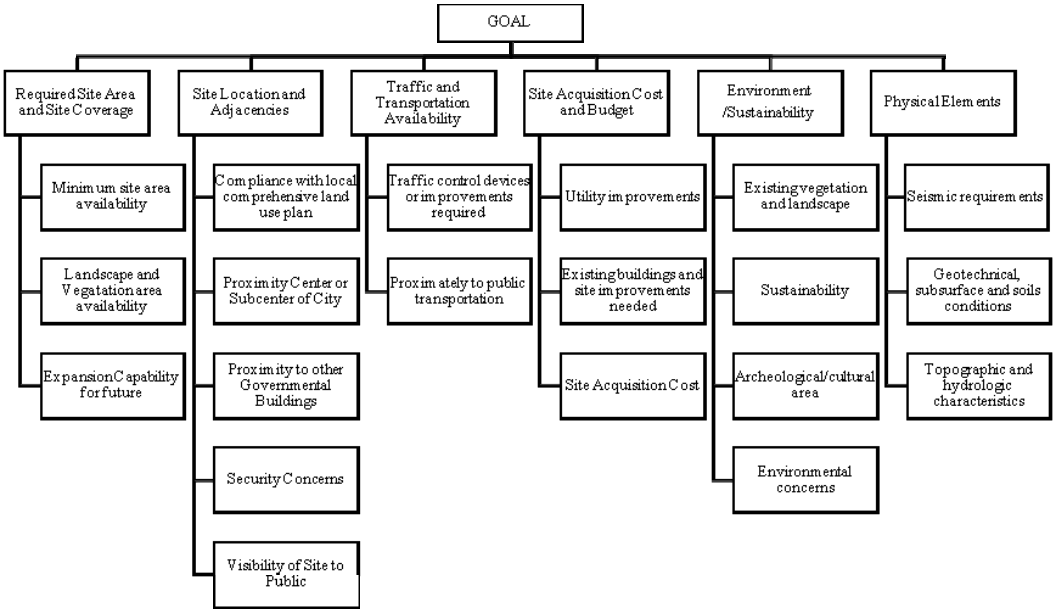


Figure 1. Hierarchic decision model of courthouse selection problem

Hierarchical hesitant fuzzy linguistic prototype that contains hesitant linguistic evaluations of multiple experts on multiple criteria is used as the method of the study. In this algorithm, linguistic term sets is used "together with context free grammar" such as ''at most medium importance'', ''between low and high importance'' etc[6].After decision model is developed, main criteria is evaluated by experts. Table 1 shows each expert's pairwise evaluation of main criteria. As seen in Table 1, some experts hesitate when they were doing pairwise comparison of criteria. For example, expert 1's preference of C1 in relation to C3 is ''at least medium importance". Due to space constraints all pairwise matrix is not given in here. However, all steps of method on one pairwise comparison matrix is explained in the paper. In table 1, all the evaluation set of experts are linguistic and it is needed to be transformed

into discrete sets. In table 2 enveloped matrix of first expert's linguistic evaluation is exhibited. For example, 'at least high importance' can be expressed as {hi, vhi, ai} and then it can be displayed [hi, ai] discrete set. Like the case for expert one, each expert's linguistic evaluations of criteria changed into enveloped matrix however it is not disclosed in here due to wording restrictions.

Table 1. Expert's pairwise evaluation of matrix of main criteria on the basis of goal

1.Expert

Main criteria	C1	C2	C3	C4	C5	C6
C1	-	at least hi	at least mi	mi	at most vhi	at least mi
C2	at most vli	-	lower than hi	mi	hi	at least mi
C3	at most mi	higher than li	-	at least hi	hi	at least mi
C4	mi	mi	at most li	-	at least mi	at least mi
C5	at least li	li	li	at most mi	-	at least mi
C6	at most mi	at most mi	at most mi	at most mi	at most mi	-

2.Expert

Main criteria	C1	C2	C3	C4	C5	C6
C1	-	lower than vli	higher than vli	mi	higher than li	Li
C2	higher than vhi	-	vli	mi	at least hi	at least hi
C3	lower than vli	vhi	-	at least hi	vli	Mi
C4	mi	mi	at most li	-	at most li	at most mi
C5	lower than hi	at most li	vhi	at least hi	-	higher than mi
C6	hi	at most li	mi	at least mi	lower than mi	-

3.Expert

Main criteria	C1	C2	C3	C4	C5	C6
C1	-	higher than mi	hi	vli	mi	higher than li
C2	lower than mi	-	mi	ni	vli	lower than vhi
C3	li	mi	-	ni	vli	Vhi
C4	vhi	ai	ai	-	ni	Ni
C5	mi	vhi	vhi	ai	-	higher than vhi
C6	lower than hi	vli	vli	ai	lower than vli	-

4.Expert

Main criteria	C1	C2	C3	C4	C5	C6
C1	-	lower than hi	lower than hi	higher than ni	lower than hi	at most ai
C2	higher than li	-	mi	vhi	vhi	Hi
C3	higher than li	mi	-	lower than vhi	higher than vhi	Vhi
C4	lower than ai	vli	higher than vli	-	hi	higher than hi
C5	higher than li	vli	higher than vli	li	-	at most hi
C6	at least ni	li	vli	lower than li	at least li	-

Table 2. Enveloped matrix of evaluation of first expert

Main criteria	C1	C2	C3	C4	C5	C6
C1	-	[hi, ai]	[mi, ai]	[mi,mi]	[ni,vhi]	[mi, ai]
C2	[ni, li]	-	[ni,hi]	[mi,mi]	[hi,hi]	[mi, ai]
C3	[ni,mi]	[li, ai]	-	[hi, ai]	[hi,hi]	[mi, ai]
C4	[mi,mi]	[mi,mi]	[ni, li]	-	[mi, ai]	[mi, ai]
C5	[vli,ai]	[li,li]	[li,li]	[mi,mi]	-	[mi, ai]
C6	[ni,mi]	[ni,mi]	[ni,mi]	[ni,mi]	[ni,mi]	-

Table 3. Numerical equivalent of the linguistic expression of first expert

Main criteria	C1	C2	C3	C4	C5	C6
C1	-	[4, 6]	[3, 6]	[3 ,3]	[0 , 5]	[3 , 6]
C2	[0, 2]	-	[0, 4]	[3 ,3]	[4 ,4]	[3 , 6]
C3	[0, 3]	[2 ,6]	-	[4 ,6]	[4 ,4]	[3 , 6]
C4	[3 ,3]	[3 ,3]	[0, 2]	-	[3, 6]	[3 , 6]
C5	[1, 6]	[2, 2]	[2, 2]	[3 ,3]	-	[3 , 6]
C6	[0, 3]	[0, 3]	[0, 3]	[0, 3]	[0, 3]	-

In table 3 numerical equivalent of the linguistic expression of the first expert is presented. After this stage optimistic and pessimistic collective preferences values using 2-tuples operations can be calculated. For instance, the optimistic collective preference and pessimistic collective preference values for C1 with respect to C2 is calculated respectively as follows:

$$P^{+}_{c12} = \Delta\left(\frac{1}{4}(\Delta^{-1}(ai,6) + \Delta^{-1}(vli,1) + \Delta^{-1}(ai,6) + \Delta^{-1}(hi,4)\right) = \Delta\left(\frac{1}{4}(6+1+6+4) = \Delta(4.25) = (hi,+0,25)$$

$$P^{-}_{c12} = \Delta\left(\frac{1}{4}(\Delta^{-1}(hi,4) + \Delta^{-1}(ni,0) + \Delta^{-1}(mi,3) + \Delta^{-1}(\mathrm{n}\,i,0)\right) = \Delta\left(\frac{1}{4}(4+0+3+0) = \Delta(1,75) = (li,-0,25)$$

All obtained value is presented in Table 4 and Table 5.

Table 4.Optimistic collective preferences matrix of main criteria

	C1	C2	C3	C4	C5	C6
C1	-	[hi,+0,25]	[vhi,0]	[mi,+0,25]	[vhi,-0,50]	[vhi,0]
C2	[hi,+0,25]	-	[mi,-0,25]	[mi,-0,25]	[vhi,0]	[ai,-0,50]
C3	[vhi, 0]	[hi,+0,25]	-	[hi,+0,25]	[mi, 0]	[vhi,-0,25]
C4	[hi,+0,25]	[mi,+0,25]	[vhi, 0]	-	[mi, 0]	[hi,-0,25]
C5	[vhi,-0,25]	[mi,-0,50]	[mi,+0,25]	[hi,+0,25]	-	[ai,-0,50]
C6	[hi,+0,25]	[mi,+0,25]	[li, 0]	[hi,+0,25]	[mi,+0,25]	-

Table 5. Pessimistic collective preferences matrix of main criteria

	C1	C2	C3	C4	C5	C6
C1	-	[li,-0,25]	[li, 0]	[li,-0,25]	[vli,+0,25]	[li,-0,25]
C2	[li,-0,25]	-	[li, -0,25]	[mi,-0,25]	[hi,-0,50]	[mi,-0,25]
C3	[vli, 0]	[mi,+0,25]	-	[li, 0]	[mi,-0,25]	[hi,0]
C4	[mi,-0,25]	[mi,+0,25]	[li, -0,25]	-	[li,-0,25]	[li,-0,25]
C5	[li,-0,50]	[li, 0]	[mi, 0]	[mi, 0]	-	[mi,-0,25]
C6	[vli, 0]	[vli,-0,50]	[vli,+0,25]	[li+0,25]	[vli,-0,50]	-

After the calculation of optimistic and pessimistic collective preferences values, interval values of each criteria can be calculated. This interval's upper and lower bound is average of optimistic and pessimistic collective preferences values;

$$[((hi,+0{,}25) + (vhi,+0) + (mi,+0{,}25) + (vhi,-0{,}50) + (vhi,0))/5,$$

$$(li,-0{,}25) + (li,\ 0) + (li,-0{,}25) + (vli,+0{,}25) + (li,-0{,}2))/5]$$

$$= (hi,\ +04;\ li,\ -0{,}3)$$

Then, "linguistic intervals" are transformed to "interval utilities". Subsequently, "midpoints of interval utilities" are attained. Finally weightings are obtained by "normalizing those midpoints". In Table 6, linguistic intervals of the criteria, interval utilities related with this interval, midpoints and obtained weightings of each main criteria are shown. According to Table 6 the highest weighted criteria is C3 namely, 'traffic and transportation'. Second the most weighted criteria is C5, namely, 'environmental impact and sustainability' and the least weighted criteria related to courthouse site selection problem is C6 that is 'physical elements (topography and hydrology)'. In Table 7 the evaluation of weightings of sub-criteria are shown. Accordingly, the most weighted sub criteria is C31 namely, 'traffic control devices or improvements required' and the second most weighted criteria is C32 that is, 'proximity to public transportation', and the least significant criteria is C23, 'proximity other governmental buildings'.

Table 6. Linguistic intervals, midpoints and weight of each criteria.

Criteria	Linguistic Intervals	Interval Utilities		Midpoints	Weights
C1	[h, +04; li, -0,3]	4,40	1,70	3,05	0,169
C2	[hi,-0,15; li,+0,5]	3,85	2,50	3,18	0,176
C3	[hi,+0,05; mi,-0,4]	4,05	2,60	3,33	0,185
C4	[hi,-0,35; li, +0,25]	3,65	2,25	2,95	0,164
C5	[hi,+0,05; li, +0,45]	4,05	2,45	3,25	0,181
C6	[mi,+0,40; vli, +0,10]	3,40	1,10	2,25	0,125

Table 7. Local and global weight of sub-criteria

Criteria	Criteria Weight	Sub-Criteria Local Weight		Sub-Criteria Global Weight
C1	0,169	C11	0,347	0,059
		C12	0,340	0,058
		C13	0,313	0,053
C2	0,176	C21	0,175	0,031
		C22	0,235	0,042
		C23	0,163	0,029
		C24	0,221	0,039
		C25	0,206	0,036
C3	0,185	C31	0,560	0,103
		C32	0,440	0,081
C4	0,164	C41	0,292	0,048
		C42	0,361	0,059
		C43	0,347	0,057
C5	0,181	C51	0,253	0,046
		C52	0,378	0,068
		C53	0,135	0,024
		C54	0,233	0,042
C6	0,125	C61	0,309	0,039
		C62	0,359	0,045
		C63	0,332	0,041

4. Conclusion

Decisions made at the commencement of a courthouse construction project have key concerns for the overall success of the facility. The location selection of the building affects the functionality; sustainability; operational and economic efficiency and many other potentials of the facility. The location selection of the building is a crucial decision that identifies the balance among the initial cost of the building, and the overall cost of the facility during its lifetime. It is evident that the decision making process is highly important while selecting the building site. With these considerations, in this paper, a site selection evaluation method for the courthouses is addressed for Turkey. The proposed criteria is based on the criteria set for the U.S. General Services Administration (GSA) suggests for similar purposes and the criteria is majorly adapted by an expert group of courthouse buildings for the Turkish case. Later an expert group who are the members of the 'Courthouse Buildings Technical Commission of Ministry of Justice of Turkey' is evaluated the criteria from their point of view by using Hesitant Fuzzy Linguistic Term Set (HFLTS).

In this study, courthouse site selection criteria weighting is established and a case study is applied with the officials of the Turkish Ministry of Justice for a newly designed courthouse site selection decision. According to the results of the case study, the most weighted main criteria in courthouse site selection is related to 'traffic and transportation' circumstances and secondly is 'environmental impact and sustainability' conditions. Correspondingly, the least weighted part of the decision problem is 'physical elements (such as underground conditions)'.

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