A DECISION SUPPORT SYSTEM FOR FACILITY LOCATION SELECTION BASED ON A FUZZY HOUSE OF QUALITY METHOD

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Abstract: Companies investigate decision supports systems (DSSs) for facility location selection to reduce cost and manage risk. In this paper, a decision support system for location selection is proposed based on a house of quality (HOQ) method, adopting an analysis to fuzzy logic and triangular fuzzy numbers. Special attention is also paid to the subjective assessment in the HOQ concept. Further, the differences between decision makers are taken into account. Finally, a case study is presented to demonstrate the procedure of the proposed algorithm and identify the suitable location.

1 INTRODUCTION

Facility location selection is a multi criteria decision-making problem. Location problems involve the determination of the location of one or more new facilities in one or more of several potential sites. Obviously, the number of sites must be at least equal to the number of new facilities being located (Heragu, 2006).

Researchers applied a quality function deployment (QFD) technique for a facility location selection problem. This technique is a planning tool used to fulfill customer expectations. It is disciplined approach to product design, engineering, and production and provides in-depth evaluation of a product. QFD focuses on customer expectations or requirements, often referred to as the voice of customer. The primary planning tool used in QFD, is the house of quality (HOQ), whose basic structure is shown in Figure 1 (Besterfield et al., 2003).

Some researchers also applied the QFD approach for facility location decisions. For instance, Chuang (2002) presented approaches including a single QFD matrix for relating customer wants to facility location. Further, Partovi (2006) presented a strategic solution to a facility location problem by using the QFD, AHP, and ANP, simultaneously. He considered internal and external criteria. However, these models do not take into account the impression and vagueness of humans' judgments. Temponi et al. (1999) developed a fuzzy logic-based extension to the HOQ to capture imprecise requirements to both facilitate communication of team members and have a formal representation of requirements. Recently, Bevilacqua et al. (2006) suggested a new method that transfers the HOQ approach, typical of QFD problems to the supplier selection process.

In this paper, we develop a decision support system (DSS) for location selection on the basis of the HOQ concept, adopting an analysis based on fuzzy logic and triangular fuzzy numbers. It has been assumed that there are some locations (alternatives) and we want to select the best one according to significant criteria. To deal with vagueness of human thought, a fuzzy method is suggested to convert the location linguistic attributes into fuzzy numbers. The decision support system can be easily implemented with a spreadsheet package, such as MS Excel.

The rest of this paper is as follows: In Section 2 fuzzy sets are presented. Sections 3 and 4 present the proposed model and case study, respectively. Finally, conclusions are discussed in Section 5.

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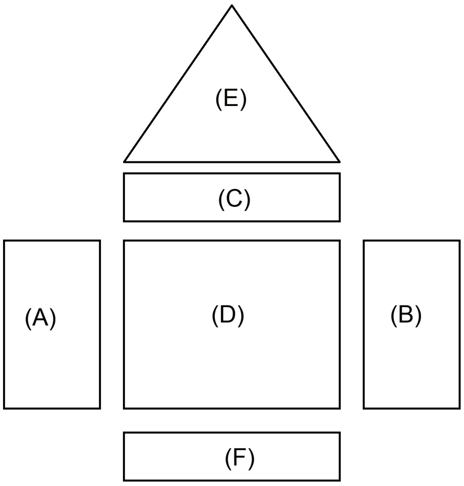

Figure 1: House of quality.

(A) Customer requirements (voice of the customer). (WHATs)
(B) Prioritized customer requirements.
(C) Technical descriptors (HOWs) (Voice of the organization).
(D) Relationship between requirements and descriptors.
(E) Interrelationship between technical descriptors.
(F) Prioritized technical descriptors.

2 FUZZY SETS THEORY

To deal with vagueness of human thought, Zadeh (1965) first introduced the fuzzy set theory, which was oriented to the rationality of uncertainty due to imprecision or vagueness. A major contribution of the fuzzy set theory is its capability of representing vague data. To deal with this type of uncertainty correctly, we can resort to fuzzy logic that is based on fuzzy sets (Zadeh, 1965). There are various types of fuzzy numbers, each of which may be suitable than others for analyzing a given ambiguous structure, the present analysis uses triangular fuzzy numbers. Figure 2 depicts a triangular fuzzy number $\tilde{A}=(l, m, u)$ (Klir and Yuan, 1995).

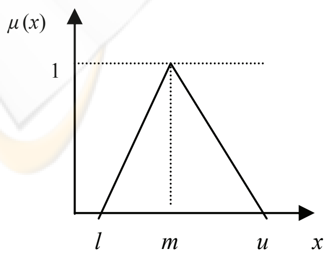

Figure 2: Triangular fuzzy number.

If we want to use fuzzy sets in applications, we will deal with fuzzy numbers operations. Let $\tilde{A}=(a, b, c)$, $\tilde{E}=(d, e, f)$, denote fuzzy numbers followed by Eqs. (1) and (2)

$$\tilde{A}\oplus\tilde{E}=(a+d,\ b+e,\ c+f) \quad (1)$$

$$\tilde{A}\otimes\tilde{E}=(a\times d,\ b\times e,\ c\times f) \quad (2)$$

3 PROPOSED MODEL

Suppose that there are a number of locations (alternatives) and we want to select the best one according to the given significant criteria. The main steps of our proposed model are as follows:

Step 1: List the customer requirement (i.e., product criteria, or WHATs).

Step 2: List the technical descriptors (i.e., location criteria, or HOWs).

Step 3: Determine prioritized customer requirement. The decision maker determines a weight by linguistic variables. Triangular fuzzy numbers are used to quantify the linguistic variables.

Step 4: Determine a weight of each decision maker (DM), in which $r_{i.}$ is the weight of DM*i*. This parameter can be determined by a manager of a company. These variables are designed according to authority, experience, and the responsibilities of different DMs. In addition, Eq. (3) should be satisfied.

$$\sum_{i=1}^{k} r_i = 1 \quad (3)$$

Step 5: Calculate an aggregated weight for WHATs: The weights assigned by the decision-makers for customer requirement should be aggregated. Aggregated weight (w_i) is computed by the following equation:

$$w_i=(r_1\otimes w_{i1})\oplus(r_2\otimes w_{i2})\oplus\ldots\oplus(r_n\otimes w_{in}) \quad (4)$$

where, k is the number of WHATs, and n is the number of decision-makers ($i = 1,\ldots,k$).

Step 6: Determine the relationship between requirements and descriptors: Every DM was asked to express an opinion by using the linguistic variables on the impact of each HOWs on each WHATs. It is worthy noting that triangular fuzzy numbers are used to quantify the linguistic variables.

Step 7: Compute the aggregated weight, (a_{ij}), between WHATs and HOWs by Eq. (5).

$$a_{ij}=(r_1\otimes a_{ij1})\oplus(r_2\otimes a_{ij2})\oplus\ldots\oplus(r_n\otimes a_{ijn}) \quad (5)$$

where, k is the number of WHATs, n is the number of decision-makers, ($i = 1,...,k$), ($j = 1,...,m$), and m is the number of HOWs.

Step 8: Determine prioritized technical descriptors. Now we can complete the HOQ, calculate the weights of the HOWs (f_i), average the aggregated weight for WHATs (w_i), with the aggregated weight between WHATs and HOWs (a_{ij}), according to Eq. (6).

$$f_j = \frac{1}{k} \otimes [(w_1 \otimes a_{1j}) \oplus ... \oplus (w_k \otimes a_{kj})] \quad (6)$$

Again, these variables are triangular fuzzy numbers.

Step 9: Determine the impact of each location on the attributes considered. It is necessary to assess each location vis-à-vis the attribute in question and combine said assessments with the weight of each attribute in order to establish a final ranking. In the same way as before, the linguistic variables are used quantified by means of triangular fuzzy numbers, then the DMs' assessment or LR (LR = Location Rating), are aggregated according the following equation:

$$LR_{hj} = (r_1 \otimes lr_{hj1}) \oplus (r_2 \otimes lr_{hj2}) \oplus ... \oplus (r_n \otimes lr_{hjn}) \quad (7)$$

$$h = 1,\dots,p \;,\; j = 1,\dots,m$$

where, m, p, and n are the number of attributes, locations, and decision makers, respectively.

Step 10: Calculate the FSI index that expresses the degree to which a location satisfies a given requirement. This index is a triangular fuzzy number obtained from the previously calculated scores by Eq. (8).

$$FSI_h = \frac{1}{m} \otimes [(LR_{h1} \otimes f_1) \oplus ... \oplus (LR_{hm} \otimes f_m)] \quad (8)$$

Step 11: Defuzzify the FSI index and Ranking. The simple and popular method is adopted to defuzzify the FSI index. A defuzzified triangular fuzzy number, $\tilde{A} = (l, m, u)$, is obtained by Eq. (9).

Finally, the final scores can be ranked.

4 CASE STUDY

In this section, we consider a real-case study. A famous company in Iran that manufactures bicycle components, such as cranks, hubs, rims, and so forth wants to establish another factory to expand its supply chain. Therefore, this company should focus on product design during location selection process. Because customer service is very important, the company wants to be as close its customers as possible. Preliminary investigation is shown that three big sites, namely Isfahan, Tabriz, and Yazd, are considered as the three most desirable locations in this study. The data are collected by means of interviews with three company buyers.

Step 1: Reasonable Cost, Nice Finish, Lightweight, Strengthm and Durable are five customer requirements.

Step 2: The customer needs and expectations are expressed in terms of the customer requirement, and the QFD team must come up with location criteria (HOWs). Five location criteria are: Economic (EC), Technological (TE7), Social (SO), Political (PO), and Environmental (EC) criteria.

Step 3: Let U = {VL, L, M, H, VH} be the linguistic set used to express opinions on the group of attributes (VL = Very Low, L = Low, M = Medium, H = High, VH = Very High). The linguistic variables of U can be quantified by using triangular fuzzy numbers as shown in Figure 3: VL = (0, 0, 2); L = (0, 2, 5) ; M = (2, 5, 8); H = (5, 8, 10); VH = (8, 10, 10). Each of the three decision-makers establishes a level of the importance or weight of each of WHATs by means of a linguistic variable.

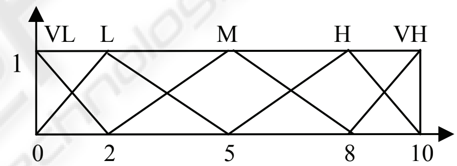

Figure 3: Linguistic scale.

$$FSI = \frac{1}{4} \otimes (L \oplus 2m \oplus U) \quad (9)$$

Step 4: The manager of this company determines a weight for each decision maker (DM). In this case, there are three decision makers. However, one of these DMs has more experience. Therefore, the manager devotes the weights as follows:
r_1=0.4, r_2=0.3, r_3=0.3

Step 5: By using Eq. (4), the aggregated weights are calculated. In our case, k=5, m=5, and n=3.

Step 6: The opinion expressed by three decision-makers, on the impact of each HOWs on each WHATs are determined.

Step 7: The aggregated weights between WHATs and HOWs are calculated by Eq. (5). Again, a_{ij} elements are triangular fuzzy numbers, as shown in Figure 4.

Step 8: Prioritized technical descriptions are calculated by Eq. (6). The fuzzy values are shown in matrix F of Figure 4.

	Economic	Technical	Social	Political	Environmental	
Cost	(6.2,8.8,10)	(3.8,6.8,9.2)	(5,8,10)	(1.2,3.8,6.8)	(4.1,7.1,9.4)	(2.6,5.3,7.9)
Nice finish	(2.9,5.9,8.6)	(2.6,5.3,7.9)	(0.6,2.9,5.9)	(5.9,8.6,10)	(0.1.4,4.1)	(2.1,4.7,7.4)
Lightweight	(2.3,5,7.7)	(7.1,9.4,10)	(0.6,1.5,3.8)	(4.1,7.1,9.4)	(0,2,5)	(5.9,8.6,10)
Strength	(3.8,6.8,9.2)	(2.9,5.9,8.6)	(0.6,2.9,5.9)	(6.2,8.8,10)	(0,1.2,3.8)	(4.1,7.1,9.4)
Durable	(1.2,3.8,6.8)	(5,8,10)	(1.2,3.8,6.8)	(5.9,8.6,10)	(0.6,2.9,5.9)	(0.8,3.2,6.2)
	f_1	f_2	f_3	f_4	f_5	
	(52.3,177.8,348.2)	(73.1,209.2,373.9)	(21.2,101,6,258.2)	(69.8,211.6,377.7)	(11.1,79.2,211.8)	

Figure 4: Completed fuzzy-HOQ.

Table 1: Calculation of the FSI index.

	L	M	U
Isfahan	187.2	324.2	440.3
Tabriz	109.8	248.9	392.2
Yazd	187.2	322.2	437.2

Table 2: Defuzzification.

Alternative	Score	Ranking
Isfahan	319	1
Tabriz	250	3
Yazd	317	2

Step 9: In this step, the impact of each potential location on the attributes considered. By using Eq. (6), location ratings are calculated.
Step 10: The FSI index is calculated by using Eq. (8). Table 1 illustrates the related results.
Step 11: Triangular fuzzy numbers are defuzzified by Eq. (9). Now, the alternatives can be ranked. Ultimate ranking and scores are given in Table 2. According to this table, Isfahan is the best alternative for establishing a new factory.

5 CONCLUSIONS

Facility location selection in any industry is a multi criteria decision-making process. Expertise, experience, authority, and the responsibilities of different decision makers (DMs) influence on the results. The fuzzy logic can overcome the vagueness of human opinion. In this paper, a decision support system was proposed based on total quality management (TQM) tools, such as house of quality (HOQ) adopting an analysis to the fuzzy logic and triangular fuzzy numbers. The linguistic variables were used to quantify variables. The problem can be solved by our proposed algorithm very quickly. We conclude that this algorithm can be useful for practitioners. Further research may be investigated to determine the DMs' weights by another method, such as a fuzzy data envelopment analysis (DEA). Besides, our proposed algorithm can be applied effectively to various issues, such as performance assessment, business strategies, policy making, and other selection problems.

REFERENCES

Chuang, P., 2002. *A QFD approach for distribution's location model*. International Journal of Quality & Reliability Management 19 (8/9) 1037–1054.

Besterfield, D.H., Michna, C.B., Besterfield, G.H., Sacre, M.B., 2003. *Total Quality Management*. Third Edition, Pearson Education. New Jersey.

Bevilacqua, M., Ciarapica, F.E., Giacchetta, G., 2006. *A fuzzy QFD approach to supplier selection*. Journal Purchasing and Supply Management 12 (1) 14-27.

Heragu, S.S., 2006. *Facilities Design*, Second Edition, iUniverse Publishing Co., Lincoln, NE.

Klir, G.J., Yuan, B., 1995. *Fuzzy sets and fuzzy logic: theory and applications*. Englewood Cliffs. NJ: Prentice-Hall Co.

Partovi, F.Y., 2006. *An analytic model for locating facilities strategically*. Omega 34 (1) 41-55.

Temponi, C., Yen, J., Tiao, W.A., 1999. *House of quality: a fuzzy logic based requirements analysis*. European Journal of Operational Research 117 (2) 340–354.

Zadeh, L.A., 1965. *Fuzzy sets*. Information and Control 8 (1) 338-353.