Journal of Industrial Engineering 4 (2009) 29- 36

Fuzzy Centroid-Based Method Applied to Customer Requirements Ranking in Diba Fiberglass Company

Esmaeil Mehdizadeh[a,]*, Raheleh Alami[a]

[a]*Department of Industrial Engineering, Islamic Azad University, Qazvin Branch, Qazvin, Iran*

Received 23 Jun., 2009; Revised 18 Jul., 2009; Accepted 15 Aug., 2009

Abstract

The purpose of this study is to introduce an application of fuzzy centroid-based approach to ranking the customer requirements using QFD with competition considerations for Diba Fiberglass, an Iranian Company. The illustrated approach, not only focuses on the normal fuzzy numbers, but also considers the non-normal fuzzy numbers to capture the true customer requirements. To this end, first, we provide a concise and operational description of the fuzzy centroid-based approach to ranking the customer requirements in QFD. Then, we focus on the first steps of house of quality (HOQ), which are essentially the customer inputs in QFD with fuzzy considerations including: customer direct ratings, fuzzy representation of customers' assessments, company performance ratings, competitive priority ratings and final importance ratings. The QFD technique can help Diba Fiberglass Company to make the right decision, which will result in higher improvement. According to the 10 customers' assessments of the relative performance of the three companies and seven WHATs, a customer comparison matrix is obtained.

Keywords: Quality Function Deployment, Fuzzy Centroid-Based Method, Customer Requirement, Diba Fiberglass Company.

1. Introduction

Quality function deployment (QFD), introduced in Japan following the seminal work of Akao [1], is a customer-driven quality management system that aims to create higher customer satisfaction [20]. It has been widely used in order to translate customer requirements to a product's technical attributes [4]. A typical QFD system consists of four phases [10]: *Phase I* translates customer needs into technical measures (also called product design specifications); *Phase II* translates important technical measures into parts characteristics; *Phase III* translates important parts characteristics into process operations; and *Phase IV* translates key process operations into day-today production requirements. *Phase I*, also called house of quality (HOQ), is of fundamental importance in QFD. To facilitate applications, the HOQ process is divided into nine steps [2]: *Step 1* Customer needs (WHATs); *Step 2 R*elative importance ratings; *Step 3* Competitive analysis; *Step 4* Final importance ratings; *Step 5* Technical measures (HOWs); *Step 6* Relationship between WHATs and HOWs; *Step 7* Technical ratings; *Step 8* Technical comparison and *Step 9* Final technical ratings. In this paper, we focus on the first four steps of HOQ, which are

Essentially the customer inputs in QFD. Correct rating of the importance of every customer requirement is essential to the QFD process because it will largely affect the final target value of a product's technical attributes; also, obtaining the final importance ratings of the customer needs is a crucial step in applying QFD. Based on these ratings, a company can purposefully design and develop a product to achieve higher customer satisfaction and thus more competitive advantages. Today, the success of a product in a competitive market place depends not only on how well it meets the customers' requirements, but also how it compares with competitors' products. Therefore, it is important to integrate competitive analysis into product design and development. Then, the ranking of customer requirements for the allocation of development resources should be based on competitive analysis as well. In addition, in real applications, fuzzy mathematics is usually more appropriate than crisp models to capture the true customer requirements.

Many papers have been published in the field of competitive priority rating (See [5]), and several rating methods such as precise scoring methods [9], group decision-making techniques [16] and [11] and AHP method [1, 12] have been proposed. However, customers'

*Corresponding author e-mail: emehdi@qiau.ac.ir

opinions are often vague and ambiguous; hence, conveying multiple meanings [8, 13]. Fuzzy mathematics is used in AHP [14]. From the customer perspective, all the above methods have common characteristics. They are coordinated with the basic spirit of QFD, customer-driven design. However, in today's highly competitive environment, several products can satisfy the customer. In such circumstances, simply meeting customer requirements cannot guarantee a successful product. Companies must consider competitors' positions to make sure that their own products would not lag behind their competitors' products. In the current literature, there are some existing methods that incorporate competitors' information to prioritize customer requirements. The first widely-used method is the sales point method. The second is the entropy method and the third method is rating method in a competitive environment presented by Lai et al. [5].

Cohen [6] defines a sales point as a method that "contains information characterizing the ability to sell the product or service, based on how well each customer need is met". Sales point can be categorized into three types: Strong, Moderate, and Poor, indicating the business opportunity from most to least, respectively. Every customer requirement can be categorized into the above three categories. Based on this categorization, a coefficient can be assigned to each type of sales point. The most commonly used values are 1, 1.25, and 1.5, corresponding to poor sales point, moderate sales point, and strong sales point, respectively. The final importance weight is computed as follows:

Final importance weight = relative importance rating $\times$ sales point value

The use of the entropy method in product planning was proposed by Chan et al. [4]. This method analyzes the customers' assessment of a company's performance and its competitors' information, to generate the competitive priority ratings. It gives the highest value to the customer requirement in which all the companies perform the same. It assumes that when all companies perform equally well, it means there is a good opportunity to be outstanding. In fact, these assumptions may not be correct in many situations.

Lai et al. [5] proposed a new customer requirements ranking method that considers competitors' information. The proposed rating method will provide the final weight from three perspectives: competition, performance and customers. The conceptual process of this model is presented in four steps: the first step is to derive the customer requirements structure. The second step presents how well each competitive product performs on each customer requirement. The third step subsumes four minor steps. First, the fuzzy performance rating matrix is used to compare the performance of own product and competitors. Based on the comparison, the competition position is assessed by classifying the performance into several ranges. Then,, an algorithm to derive the fuzzy weight from competition and performance point of view is developed. Finally, the weight is defuzzified and normalized for the next step. In the final step, the importance weight information from customers is incorporated. The final importance weight combining the factors of competition, performance, and customer, then, can be obtained.

All previous fuzzy customer requirements ranking methods use only normal fuzzy number. Mehdizadeh et al. [17] illustrated that previous methods are incorrect and lead to some misapplications if the fuzzy number is non-normal. Mehdizadeh [18] extended the recent work and presented a new approach based on fuzzy centroid-based method to ranking customer requirements with competition consideration. His proposed method, not only focuses on the normal fuzzy numbers, but also considers the non-normal fuzzy numbers instead of crisp numbers to capture the true customer requirements.

The purpose of this study is to illustrate an application of the fuzzy approach presented by Mehdizadeh [18] for ranking the customer requirements with competition consideration for an Iranian Company (Diba Fiberglass Company). Requiring less and straightforward information from customers and making perfect use of customer input to reveal the relative importance of customer needs; they are more objective and easier to apply.

The rest of this paper is organized as follows: Section 2 presents the details of the fuzzy centroid-based method. Section 3 provides experimental results, and conclusions are presented in the final section.

2. Fuzzy Centroid-Based Method

In this section, fuzzy centroid-based method applied to customer requirements ranking in QFD that was proposed by Mehdizadeh [18] to prioritize the customer needs *W1, W2, …, Wm,* when the company is compared with its competitors will be described. The method is based on corrected centroid-based distance method by Wang et al. [12]. Correct centroid-based distance method can be studied in both normal fuzzy number and non-normal fuzzy number.

A fuzzy number is a convex fuzzy subset of the real line *R* and is completely defined by its membership function. Let $\tilde{A}$ be a fuzzy number, whose membership function $f_{\tilde{A}}(x)$ can generally be defined by Dubois and Prade [7] as:

$$f_{\tilde{A}}(x)=\begin{cases} f_{\tilde{A}}^{l}(x), & a\le x\le b,\\ \omega, & b\le x\le c,\\ f_{\tilde{A}}^{R}(x), & c\le x\le d,\\ 0, & \textit{Otherwise}, \end{cases}$$

Where $0 \prec \omega \le 1$ is a constant, $f_{\tilde{A}}^{L}(x)$ and $f_{\tilde{A}}^{R}(x)$ are two strictly monotonically and continuous mappings from *R* to the closed interval [0, ω]. If w=1, then $\tilde{A}$ is a normal fuzzy number; otherwise, it is said to be a non-normal fuzzy number. If the membership function $f_{\tilde{A}}(x)$ is piecewise linear, then $\tilde{A}$ is referred to as a trapezoidal fuzzy number and is usually denoted by $\tilde{A}=[a,b,c,d;\omega]$ or $\tilde{A}=[a,b,c]$ if $\omega=1$, which is plotted in Fig. 1. In particular, when $b=c$, the trapezoidal fuzzy number is reduced to a triangular fuzzy number denoted by $\tilde{A}=[a,b,c;\omega]$ or $\tilde{A}=[a,b,c]$ if $\omega=1$. So, triangular fuzzy numbers are special cases of trapezoidal fuzzy numbers.

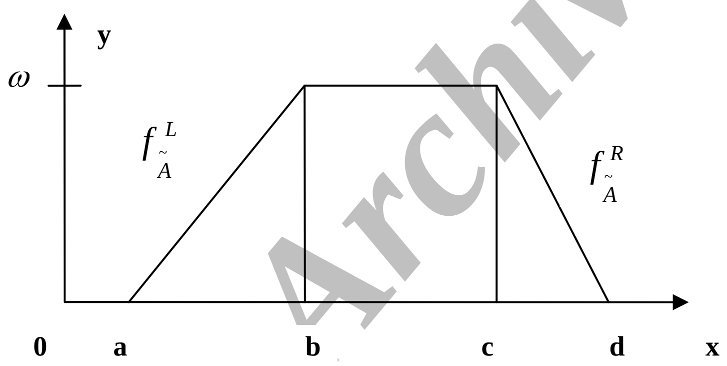

Fig. 1. Trapezoidal Fuzzy Number

Cheng [5], suggested a centroid-based distance method for ranking fuzzy numbers. The method utilizes the Euclidean distances from the origin to the centroid point of each fuzzy number to compare and rank the fuzzy numbers. Wang et al. [21] revealed that in real applications, the centroid formulae for fuzzy numbers provided by Cheng [5] are incorrect. To avoid possible more misapplications or spread in the future, they present in their paper the correct centroid formulae for fuzzy numbers and justify them from the viewpoint of analytical geometry. For the trapezoidal fuzzy numbers they present following formula:

$$\tilde{x}(\tilde{A})=\frac{1}{3}[a+b+c+d-\frac{dc-ab}{(d+c)-(a+b)}]$$

$$\tilde{y}(\tilde{A})=\omega.\frac{1}{3}[1+\frac{c-b}{(d+c)-(a+b)}] \quad (1)$$

For normal trapezoidal fuzzy number, $\tilde{A}=[a,b,c,d]$, the last formula can be simplified as

$$\tilde{y}(\tilde{A})=\frac{1}{3}[1+\frac{c-b}{(d+c)-(a+b)}]$$

Since triangular fuzzy numbers are special cases of trapezoidal fuzzy numbers with *b*=*c*, for any triangular fuzzy number with a piecewise linear membership function, its centroid can be determined by

$$\tilde{x}(\tilde{A})=\frac{1}{3}[a+b+c]$$

$$\tilde{y}(\tilde{A})=\frac{1}{3}.\omega$$

In particular, for normal triangular fuzzy number $\tilde{A}=[a,b,c]$, the last formula becomes a constant. That is

$$\tilde{y}(\tilde{A})=\frac{1}{3}.\omega$$

In the previous customer requirements ranking methods, always normal fuzzy number is considered, namely, $\omega=1$ and $\tilde{y}(\tilde{A})=\frac{1}{3}$. However, previous methods proved to be incorrect if the fuzzy numbers are non-normal; therefore, here in this work, we use non-normal fuzzy number, namely, $\omega\ne 1$.

2.1. Customer direct ratings

Suppose that *m* customer needs have been collected and identified, denoted by $W_1,...,W_m$. In traditional approaches, customers are asked to assign positive numbers to the *Wj*'s, with a small number indicating unimportance and a large number importance. In marketing and psychological practices, there are many scales to measure and quantify qualitative attributes [3]. As people's assessment of an attribute's importance is usually expressed in linguistic terms such as `unimportant' and `very important' and then transferred to crisp numbers, a frequently used scale is the following 9-point scale:

Table 1
Nine-point scale for people's assessment of qualitative attributes

Very Unimportant	-	unimportant	-	medium	-	important	-	Very important
1	2	3	4	5	6	7	8	9

The rationale behind such a 1-to-9 rating scale comes from the many tests constructed by Saaty [9]. It is simple and easy to use and also includes enough information that people provide on the attributes measured.

However, it is also well-recognized that people's assessments of qualitative attributes are always subjective and thus imprecise, and the linguistic terms that people use to express their feelings or judgments are vague in nature. Using objective, definite and precise numbers to represent linguistic assessments are, although widely adopted, not very reasonable. A more rational approach is to assign an interval to a vague linguistic term so that its vagueness can be captured. For example, rather than using numbers 7 and 9 to represent `important' and `very important', we may assign intervals [6, 8] and [8 10] to these two linguistic assessment terms to express their vagueness. In mathematics, this idea can be built into the nice framework of fuzzy set theory and trapezoidal and triangular fuzzy numbers (TFNs) can be used to represent people's subjective assessment.

2.2. Fuzzy representation of customers' assessments

Within the framework of fuzzy set theory, instead of assigning definite ratings of 1 to 9 to represent the assessments of customer needs from `very unimportant' to `very important', as pointed out by Chan et al. [4], we express them as special fuzzy sets from $M1$ = `approximately 1' to $M9$ = `approximately 9' in order to take the imprecision of people's qualitative assessments into consideration. In the previous works, these fuzzy sets specified as normal triangular fuzzy numbers but we consider non-normal triangular fuzzy numbers as:

Table 2
General triangular fuzzy numbers

Very unimportant	-	unimportant	-	medium	-	important	-	Very important
M1	M2	M3	M4	M5	M6	M7	M8	M9
[1 1 2,w1]	[1 2 3,w2]	[2 3 4,w3]	[3 4 5,w4]	[4 5 6,w5]	[5 6 7,w6]	[6 7 8,w7]	[7 8 9,w8]	[8 9 9,w9]

2.3. Company performance ratings

Now we turn to Step 3 to conduct competitive analysis. Suppose that there are k companies producing similar products, $C1,\ldots,Ck$, where $C1$ represents the company under study. Customers are asked to express their `feelings' or assessments of the performance of each company' s product in terms of the m customer needs, $W1, \ldots, Wm$, usually using the following 9-point scale: Suppose that, in total, q customers are surveyed and q_i customers give performance ratings for company Ci's product.

Table 3
Nine point scale for Company performance ratings

Very poor	-	poor	-	medium	-	good	-	Very good
M1	M2	M3	M4	M5	M6	M7	M8	M9
[1, 1, 2; w1]	[1, 2, 3; w2]	[2, 3, 4; w3]	[3, 4, 5; w4]	[4, 5, 6; w5]	[5, 6, 7; w6]	[6, 7, 8; w7]	[7, 8, 9; w8]	[8, 9, 9; w9]

First, for every ranking presented by customer to every need for company Ci's product, we calculate $\sqrt{(\bar{x}_i)^2 + (\bar{y}_i)^2}$ and calculate the averaging of these q_i sets of performance ratings on the m customer needs, Ci's final performance ratings are obtained and denoted as a column vector $xi = (x1i, \ldots, xmi)$.

2.4. Competitive priority ratings by proposed method

Before applying the new method concept, a quick analysis of how the company may set priorities to the identified customer needs seems in order. If company $C1$ performs much better than most companies on a customer need Wj, then further improvement seems unimportant and a lower priority could be assigned to Wj. If $C1$ performs much worse than a noticeable number of companies on Wj, then it may be difficult for $C1$ to build a competitive advantage due to the great amount of effort required for improvement. In either case, *Wj* would be assigned a lower priority. On the other hand, if all companies perform quite similarly on *Wj* , a better performance could give *C1* a unique competitive advantage. Thus, a higher priority could be assigned to *W*. If all companies' performances on *Wj* are the same, it implies a great market opportunity since a small improvement will create a significant competitive advantage. So, the highest priority could be assigned to it. Thus, the distance between centroid points of performance of the company and competitive calculated and smaller distance shows the highest priority.

2.5. Final importance ratings

Now, the traditional methods can be used for finding the final importance ratings. If company *C1* has some prior knowledge about the weights for the customer needs, say, the relative importance ratings $g = (g1, \dots, gm)$ obtained from the customers' direct assessments of the *Wj* ' s, then this set of weights can and should be adapted with the help of the $e = (e1, \dots, em)$ information obtained from the companies' performance ratings to obtain the final importance ratings $f = (f1, \dots, fm)$ of the *Wj* 's [22] :

$$f_j = g_j \times e_j, \qquad j = 1, \dots, m$$

3. Exprемental Results

Diba Fiberglass Company is a leading company which has specialized in manufacturing fiberglass product for composites industries and is the first producer of fiberglass yarn in Iran. It is widely used in GRP pipe products, automobile industries, buildings and so on. Currently, it's main products include all kind of E-glass and ECR glass fiber, Direct & Spray-up Roving, fiberglass Woven cloth, BMC and other fiberglass products. It has an annual output of glass fiber chopped strand mat totaling 5000 000 kg per year.

The most important competitors of Diba Fiberglass Company are as follows:

- Imported products of CPIC – a Chinese company- that is the largest producers of Fiber Glass in the world.
- Products of Owens Corning -American company.

Diba Fiberglass Company as a chopped strand mat producer, called company *C*1, wishes to make an improvement on the quality of a specific type of strand mat. The company must know in what direction any improvements should be made. The QFD technique can help *C*1 make the right decision, which will result in higher improvement. Suppose that from all, or a subgroup of the company's customers, 10 customers are selected to help identify customer needs for the strand mat's quality. They identify 7 needs (WHATs) that, of course, are expressed in customers' words and they are more manageable and meaningful needs. They are as follows:

W_1: steady distribution of superficial density
W2: shortened time of product saturating to resin
W3: proper continuity of product
W4: method of product packaging
W5: changing packaging method from package 12 pieces product's carton upon the pallet to nylon packaging in order to reducing 5% of price
W6: high strength of product bending
W7: product manufacturing with different sizes with regards to more varied cuttings in length and width.

According to these crisp or fuzzy ratings representing the relative importance of the WHATs perceived by customers, we can obtain the relative importance ratings of the WHATs by averaging the customers' perceptions. As shown in tables 4 and 5, it is easy to know that the following same ranking order for the ten customer needs:

Table 4
Relative importance ratings of the ten WHATs based on the first five customers' perceptions

	Customer 1		Customer 2		Customer 3		Customer 4		Customer 5	
W_m	Fuzzy	Centroid point	Fuzzy	Centroid point	Fuzzy	Centroid point	Fuzzy	Centroid point	Fuzzy	Centroid point
W_1	(3,5,7;1)	5.01	(3,5,7;1)	5.01	(3,5,7;1)	5.01	(5,7,9;1)	7.007	(3,5,7;1)	5.01
W_2	(7,9,10;0.9)	8.67	(5,7,9;0.9)	7.006	(7,9,10;0.9)	8.67	(5,7,9;0.9)	7.006	(7,9,10;0.9)	8.67
W_3	(3,5,7;0.95)	5.01	(5,7,9;0.95)	7.007	(5,7,9;0.95)	7.007	(3,5,7;0.95)	5.01	(3,5,7;0.95)	5.01
W_4	(1,3,5;0.7)	3.009	(1,3,5;0.7)	3.009	(1,3,5;0.7)	3.009	(0,1,3;0.7)	1.353	(1,3,5;0.7)	3.009
W_5	(7,9,10;1)	8.67	(5,7,9;1)	7.007	(5,7,9;1)	7.007	(5,7,9;1)	7.007	(5,7,9;1)	7.007
W_6	(1,3,5;0.8)	3.01	(1,3,5;0.8)	3.01	(0,1,3;0.8)	1.35	(0,1,3;0.8)	1.35	(1,3,5;0.8)	3.01
W_7	(7,9,10;0.9)	8.67	(7,9,10;0.9)	8.67	(7,9,10;0.9)	8.67	(7,9,10;0.9)	8.67	(7,9,10;0.9)	8.67

Table 5
Relative importance ratings of the ten WHATs based on the second five customers' perceptions

	Customer 6		Customer 7		Customer 8		Customer 9		Customer 10		result	
W_m	Fuzzy	Centroid point	Fuzzy	Centroid point	Fuzzy	Centroid point	Fuzzy	Centroid point	Fuzzy	Centroid point	Average Centroid point	Normalized Rate
W_1	(3,5,7;1)	5.01	(5,7,9;1)	7.007	(5,7,9;1)	7.007	(3,5,7;1)	5.01	(7,9,10;1)	8.67	5.9751	0.2180
W_2	(7,9,10;0.9)	8.67	(7,9,10;0.9)	8.67	(7,9,10;0.9)	8.67	(5,7,9;0.9)	7.006	(7,9,10;0.9)	8.67	8.1708	0.1985
W_3	(5,7,9;0.95)	7.007	(3,5,7;0.95)	5.01	(3,5,7;0.95)	5.01	(5,7,9;0.95)	7.007	(3,5,7;0.95)	5.01	5.8088	0.1411
W_4	(0,1,3;0.7)	1.353	(1,3,5;0.7)	3.009	(1,3,5;0.7)	3.009	(1,3,5;0.7)	3.009	(1,3,5;0.7)	3.009	2.6778	0.0650
W_5	(5,7,9;1)	7.007	(7,9,10;1)	8.67	(5,7,9;1)	7.007	(5,7,9;1)	7.007	(7,9,10;1)	8.67	7.5059	0.1823
W_6	(1,3,5;0.8)	3.01	(1,3,5;0.8)	3.01	(1,3,5;0.8)	3.01	(1,3,5;0.8)	3.01	(3,5,7;0.8)	5.007	2.8777	0.0699
W_7	(3,5,7;0.9)	5.008	(7,9,10;0.9)	8.67	(7,9,10;0.9)	8.67	(5,7,9;0.9)	7.006	(7,9,10;0.9)	8.67	8.1374	0.1977

$$W_1 \succ W_2 \succ W_7 \succ W_5 \succ W_3 \succ W_6 \succ W_4$$

Now, suppose, in the fiber glass industry market, company *C*1 has two main competitors, called companies *C*2, *C*3. Each of which produces a similar type of strand mat. In order to understand the fiber glass market and its relative position in the market, and finally to find out the priorities for further improvement, company *C*1 asks, for example, 10 customers to rate the relative performance of some of the three companies' similar products they use and are familiar with in terms of the seven WHATs . The performance rating is fuzzy and average of centroid point of each performance rating calculate and can obtained from table 6.

Table 6
Company performance ratings assessed by customers

	Company C_1										Company C_2										Company C_3									
W_m	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
W_1	5	5	5	7	5	5	7	7	5	8	7	8	7	7	7	8	7	7	8	7	7	8	7	8	8	8	8	8	8	8
W_2	8	7	8	7	8	8	8	8	7	8	3	3	1	5	3	3	1	3	5	3	5	5	5	3	3	7	3	5	7	5
W_3	5	7	7	5	5	7	5	5	7	5	3	5	5	5	3	5	3	3	5	5	1	3	1	1	3	3	1	3	5	1
W_4	3	3	3	1	3	1	3	3	3	3	7	8	7	7	5	8	7	7	8	7	5	7	5	7	5	5	7	5	7	7
W_5	8	7	7	7	7	7	8	7	7	8	3	5	3	3	5	5	3	3	5	3	5	5	3	3	3	3	5	3	5	3
W_6	3	3	1	1	3	3	3	3	3	5	8	7	8	7	5	7	7	8	7	8	5	5	7	5	7	5	3	5	7	5
W_7	8	8	8	8	8	5	8	8	7	8	1	3	1	1	3	1	1	1	1	5	7	3	5	1	3	7	5	5	3	5

According to the 10 customers' assessments of the relative performance of the three companies' similar products in terms of the seven WHATs, a customer comparison matrix according table 7 can be obtained by averaging for each company by centroid point of its customers' assessments.

$$W_1 \succ W_3 \succ W_2 \succ W_5 \succ W_7 \succ W_6 \succ W_4$$

Table 7
Customer's comparison matrix

w_m	C_1	C_2	C_3
W_1	5.9	7.3	7.8
W_2	7.7	3	4.8
W_3	5.8	4.2	2.2
W_4	2.6	7.1	6
W_5	7.3	3.8	3.8
W_6	2.8	7.2	5.4
W_7	7.6	1.8	4.4

It can be obtained final rate of each customer requirement from Tables 4 and 5 and table 8 by multiple latest column of each table as shown in table 9. Therefore:

4. Conclusions

Basically, there are two different ways to assign weights to the attributes in the general context of multiple criteria decision making (MCDM) [22]. The first is to let the customers directly provide linguistic assessments or the corresponding numerical importance ratings for the attributes concerned based on their subjective assessments. This set of weights is direct, subjective, external and relatively stable. The second way of assigning weights to the attributes is to consider several alternatives, such as different companies or products, each of which has performance scores or ratings on each of the attributes. One idea for obtaining weights for the

Table 8
Requirements' rating according to proposed method

W_m	C1	C2	C3	Ave c2:c3	ABS(c1-Ave)	1/ABS	Rate
W_1	5.9	7.3	7.8	7.55	1.65	0.606060	0.263430
W_2	7.7	3	4.8	3.9	3.8	0.263157	0.114383
W_3	5.8	4.2	2.2	3.2	2.6	0.384615	0.167176
W_4	2.6	7.1	6	6.55	3.95	0.253164	0.110040
W_5	7.3	3.8	3.8	3.8	3.5	0.285714	0.124188
W_6	2.8	7.2	5.4	6.3	3.5	0.285714	0.128188
W_7	7.6	1.8	4.4	3.1	4.5	0.222222	0.096591
						2.300646	1

Table 9
Requirements' rating according to final rates

W_m	Customer rate	Competitive rate	Customer rate × Competitive rate	Final rate
W_1	0.21800	0.263430	0.057427	0.356144
W_2	0.19850	0.114383	0.022705	0.140809
W_3	0.14111	0.167176	0.023588	0.146285
W_4	0.06506	0.110040	0.007159	0.044399
W_5	0.18230	0.124188	0.022639	0.140401
W_6	0.06992	0.124188	0.008632	0.053534
W_7	0.19770	0.096591	0.019096	0.118427

Attributes from this situation is that an attribute should be paid more (less) attention and is thus assigned a higher (lower) priority if the performance ratings of the alternatives on this attribute are less / more diverse. An attribute has the highest competitive advantage and should be assigned the highest priority if all the alternatives have the same performance [3]. The performance ratings of the alternatives on a particular attribute, after normalization, can be viewed as the attribute's weight. So, a set of normalized weights can be assigned to the attributes. Correctly rating the importance of every customer requirements is essential to the QFD process because it will largely affect the final target value of a product's technical attributes. All previous fuzzy customer requirements ranking methods use only normal fuzzy number. However, Mehdizadeh et al. [15] showed that the previous methods are incorrect and lead to some misapplications if the fuzzy number is non-normal. Mehdizadeh [16] presented a new approach based on fuzzy centroid-based method to ranking customer requirements with competition considerations.

Based on the above observations, in this paper, an application of the fuzzy approach proposed by Mehdizadeh [16] was presented for ranking the customer requirements with competition consideration for an Iranian Company (Diba Fiberglass Company). Requiring less and straightforward information from customers and making full use of customer input to reveal the relative importance of customer needs, the proposed approach is more objective and easier to apply. Seven requirements are considered and customer requirements ranking with and without competition consideration are calculated and the final importance ratings are computed.

References

[1] Y. Akao, Quality function deployment: integrating customer requirements into product design, Cambridge, MA: Productivity Press, 1990.

[2] J. L. Bossert, Quality Function Deployment, A Practitioner's Approach, Milwaukee, Wisconsin: ASQC Quality Press, 1991.

[3] G. C. Bruner II, P. L. Hensel, Marketing Scales Handbook: A Compilation of Multi-Item Measures. Chicago, IL: American Marketing Association, 1992.

[4] L. K. Chan, H. P. Kao, A. Ng & M. L. Wu, Rating the importance of customer needs in quality function deployment by fuzzy and entropy methods. International Journal of Production Research, 37(11), 2499–2518, 1999.

[5] C. H. Cheng, A new approach for ranking fuzzy numbers by distance method. Fuzzy Sets and Systems, 95. 307-317, 1998.

[6] L. Cohen, Quality function deployment: How to make QFD work for you. Massachusetts: Addison- Wesley,1995.

[7] D. Dubois, H. Prade, Operations on fuzzy numbers. International Journal of Systems Science, 9. 613–626, 1978.

[8] R. Y. K. Fung, K. Popplewell & J. Xie, An intelligent hybrid system for customer requirement analysis and product attribute

targets determination. International Journal of Production Research, 36(1), 13–34, 1998.

[9] A. Griffin, J. R. Hauser, The voice of the customer. Marketing Science, 12(1), 1–27,1993.

[10] L. R. Guinta, N. C. Praizler, The QFD Book: The Team Approach to Solving Problems and Satisfying Customers through Quality Function Deployment, New York: Amacom, 1993.

[11] E. S. Ho, Y. J. Lai & S. I. Chang, An integrated group decision-making approach to quality function deployment. IIE Transactions, 31, 553–567, 1999.

[12] E. E. Karsak, S. Sozer & S. E. Alptekin, Product planning in quality function deployment using a combined analytic network process and goal programming approach. Computers & Industrial Engineering, 44(1), 171–190, 2002.

[13] L. P. Khoo, N. C. Ho, Framework of a fuzzy quality function deployment system. International Journal of Production Research, 34(2), 299–311, 1996.

[14] C. K. Kwong, H. Bai, A fuzzy AHP approach to the determination of importance weights of customer requirements in quality function deployment. Journal of Intelligent Manufacturing, 13(5), 367–377, 2002.

[15] X. Lai, M. Xie, K. C. Tan and B. Yang, Ranking of customer requirements in a competitive environment, Computers & Industrial Engineering, 2007.

[16] Y. J. Lai, E. S. Ho and S. I. Chang, Identifying customer preferences in quality function deployment using group decision-making techniques. In Usher, U., Roy, U. and Parsaei, H. (Eds), Integrated Product and Process Development – Methods, Tools, and Technologies, Wiley, New York, NY, pp. 1-28, 1998.

[17] E. Mehdizadeh, F. Rajabi and M. R. Masoomi, Ranking of customer requirements in quality function deployment by a fuzzy method. manufacturing fundementals: Necessity and sufficiancy, Chapter 17, Modeling: Quality management, 2478-2490, 2008.

[18] E. Mehdizadeh, Ranking of customer requirements using the fuzzy centroid-based method. International Journal of Quality & Reliability Management, 27, 201-216, 2010.

[19] T. L. Saaty, The Analytic Hierarchy Process: Planning, Priority Setting, Resource Allocation. Pittsburgh, PA: RWS Publications , 1988.

[20] L. P. Sullivan, Quality function deployment. Quality Progress, 19, 39–50, 1986.

[21] Y. M. Wang, J. B. Yang, D. L. Xu, K. S. Chin, On the centroids of fuzzy numbers. Fuzzy Sets and Systems,157, 919-926, 2006.

[22] M. Zeleny, Multiple Criteria Decision Making. New York: McGraw-Hill, 1982.