A FUZZY LOGIC-BASED QUALITY FUNCTION DEPLOYMENT FOR SELECTION OF E-LEARNING PROVIDER

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ABSTRACT
According to the Internet World Stats (2010), the growth rate of internet usage in the world is 444.8 % from 2000 to 2010. Since the number of internet users is rapidly increasing with each passed year, e-learning is often identified with web-based learning. The institutions, which deliver e-learning service via the use of computer and internet, are responsible to choose the most suitable e-learning service provider for effective distance education. The purpose of this research is to identify the e-learning design requirements and to select the most suitable e-learning service provider. In this research, fuzzy logic – based Quality Function Deployment (QFD) was employed. A questionnaire was conducted in order to collect the data from a group of experts who were selected on the basis of their knowledge and expertise in related industry. By using the Converting Fuzzy data into Crisp Scores (CFCS) technique, the collected data was defuzzified. Then, the critical success factors of e-learning service providers were identified. As a result, fuzzy logic-based QFD was utilized for the selection of the e-learning service providers.
Keywords: E-learning Design, Provider Selection, Fuzzy Logic, Fuzzy - Quality Function Deployment, House of Quality, Lifelong Learning.

1. INTRODUCTION

The rapid changes and growth in information and communication technologies (ICT) provide significant opportunity to share information resources and knowledge. These developments in the last couple of decades have also led to a valuable contribution for a wide range of learning applications. E-learning has become an acceptable and modern way of distance education that is delivered via the use of computers, internet and multimedia presentation (Lau, 2000). Moreover, distance education is preferred as a valuable way of learning for lifelong learning. At this point, e-learning design is an important issue for better education service.

E-learning also moves the traditional instruction paradigm to a learning paradigm (Jönsson, 2005). The most significant difference that distinguishes traditional learning and e-learning is physical distance among participants (Robinson & Bawden, 2002). Its applications can appear with different types of designations such as web-based learning, virtual classrooms, and digital collaboration (Khalifa & Kwok, 1999; Kaplan & Leiserson, 2000). Some researchers proposed different types of e-learning (Raymond, 2000; Bose, 2003). These types are web supported – blended or mixed mode, and fully online e-learning format (Robinson & Bawden, 2002; Roffe, 2002; Bose, 2003). Khan (2001) proposed a framework that offers a list of considerable factors which would be needed for the creation of a successful experience for diverse learners. Sun et al. (2006) studied the critical factors for a successful e-learning.

The QFD process requires various inputs which are also in the form of linguistic data (human perception, judgment, and evaluation on importance of customer requirements or strengths of relationship between customer requirements and technical attributes) that is quite vague and subjective (Chen et al., 2006). Although it is really important to overcome the vagueness and imprecision in human thought for operative judgment and decision making, most of the input variables in traditional QFD are represented with crisp numerical values that also cause precise judgments. To address the ambiguity in QFD process, Khoo and Ho (1996) proposed an approach that centered on the application of fuzzy arithmetic and possibility theory. Teng and Tzeng (1996) used fuzzy multi-criteria ranking for evaluating transportation investment alternatives. Sohn and Choi (2001) proposed a fuzzy-QFD model that conveys fuzzy relationship between CAs and TRs for reliability in the context of supply chain management. In order to develop a fuzzy QFD model, another research was conducted by Yang et al. (2003) to adapt HOQ to meet the needs of buildable designs in the construction industry. A fuzzy optimization model for QFD planning process was proposed by Kahraman et al. (2004). The linguistic variables were applied in the relationship matrix to weight of CAs (Karsak, 2004). In order to aggregate the information from the group decision QFD model on the application of software design, Büyüközkan and Feyzioğlu (2005) conducted the ordered weighted geometric operator.

In this study, in order to deal with the ambiguity in QFD process, fuzzy logic is used to gather the data from each decision maker. The CFCS (Converting Fuzzy data into Crisp Scores) technique is employed to defuzzify the variables. As a result, fuzzy logic-based QFD is utilized to select the e-learning service provider.

2. THE CONCEPT OF ONLINE EDUCATION FOR LIFELONG LEARNING

As an education expert in lifelong learning, John Field defined lifelong learning as a “relative new concept” although it has traditionally been known as adult education (Field, 2003). Lifelong learning is also meant to symbolize a second chance for individuals to update their skills and qualifications. Higher education institutions have an important role to develop and provide learning opportunities for individuals. E-learning indicates a radical change in learning paradigm (Lee et al., 2007). Furthermore, in comparison to traditional learning process in e-learning process participants need to have several characteristics, such as self-motivation and self-discipline that contribute to success in e-learning process (Bose, 2003). These features make e-learning a viable learning option for lifelong learning.

3. METHODOLOGY

3.1. Fuzzy Set and Linguistic Variables

In order to deal with the 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. Especially in group decision-making process, there is also an internal uncertainty based on distinctive characteristics of the all individual decision makers. A major contribution of fuzzy set theory is its capability of representing vague data. In fact, the fuzzy set theory is a generalized form of the classical set theory that has membership functions with values in [0, 1]. A fuzzy set is a class of objects with a continuum of grades of membership. Such a set is characterized by a membership (characteristic) function, which assigns to each object a grade of membership ranging between zero and one. A triangular fuzzy number is denoted simply as $(\frac{\alpha}{\beta}, \frac{\beta}{\gamma})$ or (α, β, ɣ). The parameters α, β and, ɣ respectively denote the smallest possible value, the most promising value, and the largest possible value that describe a fuzzy event (Kahraman et al., 2003). To aggregate all individual decision makers’ opinions, a common measure is needed. Therefore, the fuzzy linguistic variables are used to represent the different aspects of human language. It also allows us to use the fuzzy linguistic variables for human words and sentences with numerous linguistic criteria, such as very low, low, medium, high, very high. The linguistic terms and corresponding fuzzy numbers are shown in Table 1.

Table 1. Linguistic Term and Corresponding Fuzzy Numbers

	Linguistic Term	Fuzzy Number
(VH)	Very High	(8,9,10)
(H)	High	(6,7,8)
(M)	Medium	(4,5,6)
(L)	Low	(2,3,4)
(VL)	Very Low	(0,1,2)

3.2. Defuzzification Method

Defuzzification is a process which needs to evaluate that a fuzzy number is characterized by its shape, spread, height, and relative location on the x-axis (Opricovic & Tzeng, 2003). In this study, the CFCS (Converting Fuzzy data into Crisp Scores) defuzzification method is executed through fuzzy aggregation procedure. The CFCS defuzzification method was first proposed by Opricovic and Tzeng (2003). By determining the left and right scores, the CFCS method provides fuzzy max and fuzzy min of fuzzy numbers. According to the membership functions of the fuzzy numbers, the total score is computed with a weighted average. A tilde “~”is placed above a symbol (*Z*) where the symbol represents a fuzzy set. If $\tilde{z}_{ij}^{d} = (\alpha_{ij}^{d}, \beta_{ij}^{d}, \gamma_{ij}^{d})$ is given for the fuzzy evaluation of decision maker d (d = 1,2,…,n) about the degree to which the criterion *i* affects the criterion *j*. The CFCS defuzzification method includes five-step algorithms described as follows:

(1) Normalization:

$$x\alpha_{ij}^{k} = (\alpha_{ij}^{k} - \min \alpha_{ij}^{k}) / \Delta_{\min}^{\max}, \tag{1}$$

$$x\beta_{ij}^{k} = (\beta_{ij}^{k} - \min \alpha_{ij}^{k}) / \Delta_{\min}^{\max}, \tag{2}$$

$$x\gamma_{ij}^{k} = (\gamma_{ij}^{k} - \min \alpha_{ij}^{k}) / \Delta_{\min}^{\max}, \tag{3}$$

where $\Delta_{\min}^{\max} = \max \gamma_{ij}^{k} - \min \alpha_{ij}^{k}$.

(2) Compute left (ls) and right (rs) normalized value:

$$x\alpha s_{ij}^{k} = x\beta_{ij}^{k} / (1 + x\beta_{ij}^{k} - x\alpha_{ij}^{k}), \tag{4}$$

$$x\gamma s_{ij}^{k} = x\gamma_{ij}^{k} / (1 + x\gamma_{ij}^{k} - x\beta_{ij}^{k}). \tag{5}$$

(3) Compute total normalized crisp value:

$$x_{ij}^{k} = \left[x\alpha s_{ij}^{k} (1 - x\alpha s_{ij}^{k}) + x\gamma s_{ij}^{k} x\gamma s_{ij}^{k} \right] / \left[1 - x\alpha s_{ij}^{k} + x\gamma s_{ij}^{k} \right]. \tag{6}$$

(4) Compute crisp values:

$$z_{ij}^{k} = \min \alpha_{ij}^{k} + x_{ij}^{k} \Delta_{\min}^{\max}. \tag{7}$$

(5) Integrate crisp values:

$$z_{ij}^{k} = \frac{1}{p} (z_{ij}^{1} + z_{ij}^{2} + \Lambda + z_{ij}^{p}). \tag{8}$$

3.3. Fuzzy - Quality Function Deployment

Quality Function Deployment is a useful tool for total quality management to develop new products and services. Furthermore QFD helps to improve the features of existing products and services. It was developed in late 1960s in Japan, by Yoji Akao (Akao, 1972). QFD charts are filled through various inputs such as questionnaires, interviews and focus groups. This increases the uncertainty in the quantification of the information. The linguistic variable is useful in dealing with situations that are identified in quantitative expressions (Wang and Chuu, 2004). In order to decrease the uncertainty in the data collected, fuzzy logic can be used (Bouchereau and Rowlands, 2000). To address the ambiguity in QFD, there are some researches are conducted Temponi et al. (1999) Bevilacqua et al. (2006), and Wang (2010). The QFD process contains four phases. The house of quality matrix is usually called as the phase one matrix, or the planning matrix (Hauser and Clausing, 1988) that is shown in Fig. 1. The HOQ is described and its process following approaches suggested by Brown (1991), and Griffin and Hauser (1992).

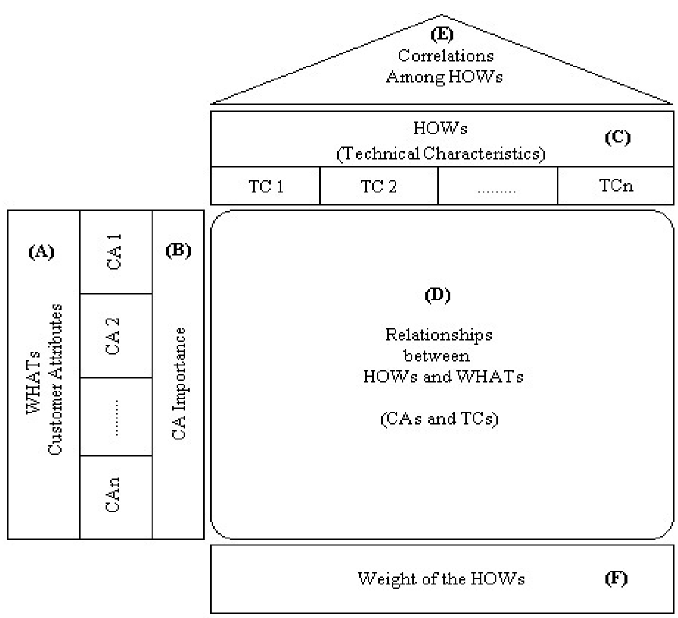


Figure 1. House of Quality

Step 1*-Identifying process of the WHATs:* In this step, the process includes the determination of customer needs, the assignment of priorities to customer attributes (CAs), and the evaluation of the customer's perception are needed (Temponi et al., 1999). The wanted benefits in a product or service in the customer's own words are customer needs and often called (CAs) or "WHATs" area (A) in Fig. 1. This step depends on expertise of the team members (Griffin and Hauser, 1992).
Step 2*-Determination process of the HOWs:* Technical characteristics (TCs), which are also called measurable requirements, are stated as the "HOWs" of the HOQ. TCs are determined by a multidisciplinary team and located on the area marked as (C) in Fig. 1.
Step 3*-Preparation of the relationship matrix:* TCs, which impact on which CAs, are judged by a team. Likewise, it is really important to identify the influence degree of TCs. This relationship between TCs and CAs is shown in the area identified as (D) in Fig. 1.
Step 4: *Elaboration process of the correlation matrix:* The physical relationships among the technical requirements are specified on an array known as "the roof matrix" and identified as (E) in Fig. 1.
Step 5: *Action plan:* The weights of the TCs, identified as area (F), are placed at the base of the quality matrix. The weights are one of the main outputs of the HOQ, and are determined by:

$$Weight(\mathrm{TC})_i = V(\mathrm{TC})_{i1} \times Im(\mathrm{CA}_1) + \ldots + V(\mathrm{TC})_{in} \times Im(\mathrm{CA}_n), \quad (9)$$

where $V(TC)_{in}$ is the correlation value of TC_i with CA_n, and $Im(CA_n)$ represents the importance or priority of CA_n.

4. APPLICATION – CASE STUDY

In this study, an illustrative case is presented. An educational institution, which aims to provide online education for lifelong learning program, is described figuratively. As e-learning service providers, 5 firms (A, B, C, D, and E), which have operations in the e-learning service industry, are selected. The e-learning provider selection model is identified by the following steps:

4.1. Selection of the Decision Makers

In this study, decision makers are selected for data collection according to their expertise in related industry. Most of the decision makers are managers/executives of e-learning users at the institutional level. 10 potential decision makers were selected and sent the invitations for this research. Moreover, in order to help the identification process of HOWs and WHATs, a broad literature research is served (Bevan, 1999; Brajnik, 2001; Signore, 2005; Li et al., 2009).

4.2. Determining the Linguistic Terms and Corresponding Fuzzy Numbers

To aggregate the opinions of each decision maker, the linguistic variables in Table 1 are employed. These variables are Very High (8;9;10), High (6;7;8), Medium (4;5;6), Low (2;3;4) and Very Low (0;1;2).

4.3. Identifying WHATs

In this step, to identify WHATs, as mentioned above, a wide-range literature review is condensed and each decision maker is asked to identify which quality characteristics should be used in this research. After the evaluations of the decision makers, 10 attributes are identified and shown in Table 2a.

Table 2. Identified WHATs and HOWs

(a)

WHATs		
1	AE	Aesthetics
2	FC	Functionality
3	RL	Reliability
4	US	Usability
5	EF	Efficiency
6	MT	Maintainability
7	PR	Portability
8	RC	Rich Content
9	CS	Customer Support
10	CT	Cost Effectiveness

(b)

HOWs		
1	CE	Certificated Education
2	TC	Technical Capability
3	QC	Quality Certification
4	RP	Reputation
5	FS	Financial Stability
6	EI	Experience in the Industry
7	QDT	Qualified and/or Experienced Design Team
8	QSS	Qualified Support Service Staff

4.4. Identifying HOWs

In order to identify HOWs, each decision maker is asked to determine which factors are important to meet the CAs for evaluating e-learning service providers. Identified HOWs are shown in Table 2b.

4.5. Calculating the Importance Degrees of WHATs

In this step, the decision makers evaluate the importance degrees of WHATs. By using the arithmetic mean method, importance degrees of WHATs are calculated. The importance degrees of each WHAT are shown in Fig. 2.

4.6. Identifying the Correlation between HOWs and WHATs

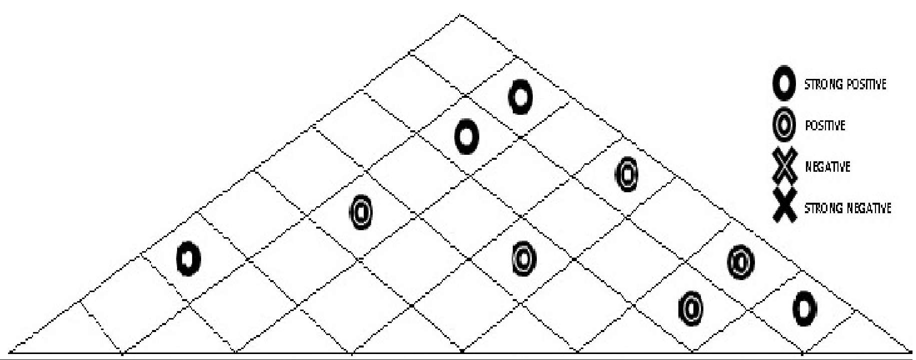
To identify the correlation between HOWs and WHATs, each decision maker is asked to evaluate the impact of each HOW on each WHAT. An evaluation example of a decision maker is shown in Table 3. Calculated correlation values are shown in Fig. 2.

Table 3. A Decision Maker's Evaluation of the Relationship between HOWs and WHATs

	UF	TC	QC	RP	FS	EI	QDT	QSS
AE	L	H	VH	H	VH	H	VH	H
FC	M	H	VL	M	H	VL	VL	VH
RL	L	VH	VH	L	VH	VH	L	M
US	VH	VH	VL	VH	VH	VL	H	L
EF	M	VL	L	M	VL	L	H	H
MT	VH	L	H	VH	L	H	VH	L
PR	VL	VH	VL	VL	VH	VL	L	L
RC	H	M	L	H	M	L	M	H
CS	H	L	H	M	VL	VL	L	VH
CT	H	M	H	L	H	L	H	VH

4.7. Computing the Weights of HOWs

By using Eq. (9), the weights of HOWs (W_i) are calculated. The calculated values are shown in Fig. 2.



				UF			TC			QC			RP		
	α	β	γ	α	β	γ	α	β	γ	α	β	γ	α	β	γ
AE	3,33	4,33	5,33	1,67	2,17	2,67	2,33	2,83	3,33	3,67	4,17	4,67	3,33	3,83	4,33
FC	4,33	5,33	6,33	2,33	2,83	3,33	3,00	3,50	4,00	1,33	1,83	2,33	2,33	2,83	3,33
RL	3,00	4,00	5,00	2,00	2,50	3,00	2,00	2,50	3,00	2,00	2,50	3,00	2,00	2,50	3,00
US	3,00	4,00	5,00	2,67	3,17	3,67	3,67	4,17	4,67	2,33	2,83	3,33	2,67	3,17	3,67
EF	5,33	6,33	7,33	1,67	2,17	2,67	2,33	2,83	3,33	2,67	3,17	3,67	1,67	2,17	2,67
MT	5,00	6,00	7,00	3,00	3,50	4,00	2,00	2,50	3,00	2,67	3,17	3,67	3,00	3,50	4,00
PR	4,00	5,00	6,00	1,33	1,83	2,33	2,67	3,17	3,67	1,33	1,83	2,33	1,33	1,83	2,33
RC	4,67	5,67	6,67	2,33	2,83	3,33	1,67	2,17	2,67	1,00	1,50	2,00	2,33	2,83	3,33
CS	4,67	5,67	6,67	2,33	2,83	3,33	1,67	2,17	2,67	1,67	2,17	2,67	1,67	2,17	2,67
CT	5,33	6,33	7,33	2,67	3,17	3,67	2,33	2,83	3,33	2,67	3,17	3,67	1,67	2,17	2,67
				W1			W2			W3			W4		
				9,49	14,32	20,16	9,89	14,89	20,89	9,06	13,82	19,59	9,20	14,03	19,87

	FS			EI			QDT			QSS		
	α	β	γ	α	β	γ	α	β	γ	α	β	γ
AE	3,67	4,17	4,67	3,33	3,83	4,33	3,67	4,17	4,67	3,33	3,83	4,33
FC	3,00	3,50	4,00	1,33	1,83	2,33	1,33	1,83	2,33	2,67	3,17	3,67
RL	2,00	2,50	3,00	3,00	3,50	4,00	1,33	1,83	2,33	1,67	2,17	2,67
US	3,67	4,17	4,67	1,67	2,17	2,67	2,33	2,83	3,33	1,67	2,17	2,67
EF	2,33	2,83	3,33	1,67	2,17	2,67	3,33	3,83	4,33	2,67	3,17	3,67
MT	2,00	2,50	3,00	2,67	3,17	3,67	2,67	3,17	3,67	1,00	1,50	2,00
PR	2,67	3,17	3,67	2,67	3,17	3,67	0,67	1,17	1,67	2,00	2,50	3,00
RC	1,67	2,17	2,67	1,33	1,83	2,33	2,33	2,83	3,33	3,33	3,83	4,33
CS	1,00	1,50	2,00	1,67	2,17	2,67	2,00	2,50	3,00	2,67	3,17	3,67
CT	2,33	2,83	3,33	2,67	3,17	3,67	3,33	3,83	4,33	3,67	4,17	4,67
	W5			W6			W7			W8		
	10,02	15,09	21,16	9,20	14,03	19,87	10,08	15,01	20,94	10,74	15,84	21,94

Figure 2. The Fuzzy - House of Quality

4.8. Measuring the Correlation of HOWs

In this step, the decision makers are asked to evaluate the correlations of HOWs. The result is shown in the roof matrix in Fig. 2.

4.9. Determining of E-learning Providers' Influence on the TCs

To determine of e-learning providers' influence on the TCs, the decision makers' opinions are collected according to the relationship between TCs and e-learning service providers. Aggregated values for each provider are given in Table 4.

Table 4. E-learning Providers' Influence on Each Attribute

Firms	HOWs																							
	CE			TC			QC			RP			FS			EI			QDT			QSS		
	α	β		α	β		α	β		α	β		α	β		α	β		α	β		α	β	
A	2,33	2,83	3,33	2,33	2,83	3,33	2,67	3,17	3,67	1,67	2,17	2,67	3,67	4,17	4,67	3,33	3,83	4,33	3,67	4,17	4,67	3,33	3,83	4,33
B	1,33	1,83	2,33	2,33	2,83	3,33	3,00	3,50	4,00	0,67	1,17	1,67	0,67	1,17	1,67	3,67	4,17	4,67	1,33	1,83	2,33	2,67	3,17	3,67
C	1,67	2,17	2,67	2,33	2,83	3,33	1,00	1,50	2,00	1,67	2,17	2,67	1,33	1,83	2,33	1,33	1,83	2,33	1,33	1,83	2,33	1,67	2,17	2,67
D	2,33	2,83	3,33	1,33	1,83	2,33	2,33	2,83	3,33	1,67	2,17	2,67	3,67	4,17	4,67	3,33	3,83	4,33	3,67	4,17	4,67	3,33	3,83	4,33
E	2,00	2,50	3,00	2,67	3,17	3,67	3,33	3,83	4,33	1,67	2,17	2,67	1,67	2,17	2,67	2,33	2,83	3,33	2,33	2,83	3,33	2,33	2,83	3,33

4.10. Converting Fuzzy Scores to Crisp Scores for Ranking Each E-learning Service Provider

In order to rank each e-learning provider (Pr), CFCS defuzzification method is employed as mentioned above. Then, the weights are calculated by using the following equation. The scores and rank of each e-learning provider are shown in Table 5.

$$Weight(\mathrm{P})_i = V(\mathrm{Pr})_{i1} \times Im(\mathrm{TC}_1) + \ldots + V(\mathrm{Pr})_{in} \times Im(\mathrm{TC}_n)/\mathrm{P}_n \qquad (10)$$

Table 5. Scores and Rank of E-learning Providers

Providers		
	SCORE	RANKING
A	50,714	1
B	38,251	4
C	32,537	5
D	48,581	2
E	42,827	3

5. DISCUSSIONS AND CONCLUSIONS

According to the final results, e-learning provider A is rated as the best choice, but the other provider C is the worst one for a good e-learning service. By using this proposed method, an alternative way of e-learning service provider selection is described. Moreover, by using this method, critical success factors for e-learning service providers can be identified. According to the evaluations of each decision maker, "Qualified Support Service Staff" has the highest score and identified as the most important factor, followed key is "Financial Stability", "Qualified and/or Experienced Design Team" and "Technical Capability", respectively. These four factors have relatively higher scores than the others including "Certificated Education", "Reputation", "Experience in the Industry", and "Quality Certification". It also indicates that human resources are among the most important features of the online education industry. A balanced combination of human resources and technological factors is needed for a successful e-learning design.

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