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A fuzzy logic-based QFD to identify key factors of e-learning design

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Abstract

Because of increasing usage of Internet, online learning has become more important issue for sustainable distance education. In order to use the internet as an effective education tool, there are many important factors in e-learning design such as web interface, e-learning software etc. The purpose of this research is to identify key factors in the e-learning design process and evaluate these identified factors by using fuzzy logic-based Quality Function Deployment. Comparisons of the experts' opinions were used to identify and analyze the relationship between customer needs and technical requirements. Finally, key factors were identified and ranked for e-learning systems.

Keywords: E-learning Design; Fuzzy Logic; Fuzzy - Quality Function Deployment; House of Quality.

1. Introduction

Over the last two decades, e-learning has become the preferred way of education. According to the Internet World Stats (2010), the growth rate of internet usage in the world is 444.8 % from 2000 to 2010. Since internet usage is rapidly increasing with each year, e-learning is usually identified with web-based learning. Quality Function Deployment has become an important tool that may help the companies understand the customer and integrate the customer's requirements into the design and production of goods and services (Madu, 2004). Most of the input variables in traditional QFD are represented by crisp numerical values, which also cause precise judgments. In this study, fuzzy logic based QFD is employed to deal with the vagueness of human thought for identifying key factors of e-learning design.

2. The Concept of E-learning

E-learning is the use of digital technologies to support and deliver some or all of the teaching and learning for a particular unit of study (Stuparich, 2001). The most significant difference that distinguishes traditional learning and e-learning is physical distance among participants (Robinson & Bawden, 2002). Most of the potential benefits of e-learning relate to the participants such as students, distance learners etc. (Robinson & Bawden, 2002). These benefits are flexibility, accessibility, own pace of study, and accommodation of different learning styles of

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participants through different activities. In addition, there are some benefits of e-learning for teachers and providers of e-learning. There are some researches that offer new methodologies for evaluation of websites (Waters, 1996; Brajnik, 2001; Mich et al., 2003; Calero et al., 2005; Zhou et al., 2008; Li et al., 2009).

3. Methodology

3.1. Fuzzy logic and linguistic variables

The human language provides a valuable opportunity (perspective) to reflect on different thoughts, opinions and beliefs in facing with many different situations. Furthermore, in the decision-making process, it is really important to understand the different aspects of human language. To deal with this vagueness of human thought, Zadeh (1965) first introduced the fuzzy set theory that was oriented to the rationality of uncertainty due to vagueness or imprecision. This theory also allows mathematical operators and programming to apply to the fuzzy domain. A fuzzy set is a class of objects with a continuum of grades of membership. A triangular fuzzy number (TFN), $\tilde{M}$, is denoted simply as $[(\alpha/\beta), (\beta/ \gamma)]$ or (α, β, γ). The parameters α, β and γ respectively denote the smallest possible value, the most promising value, and the largest possible value that describe a fuzzy event (Kahraman et al., 2003). The linguistic terms and corresponding fuzzy numbers are shown in Table 1.

Table 1. Linguistic terms 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. Fuzzy – Quality Function Deployment

QFD was developed in late 1960s in Japan, by Yoji Akao (Akao, 1972). It offers a framework for product design planning that converts customer requirements into the technical requirements of the product. Moreover, QFD has the ability to improve the features of existing products and services. QFD charts are compiled using various inputs such as questionnaires, interviews and focus groups. This increases the uncertainty in the quantification of the information. In order to decrease the uncertainty in the data collected, fuzzy logic can be used (Bouchereau & Rowlands, 2000). Many other studies (Temponi et al., 1999; Yang et al., 2003; Bevilacqua et al., 2006) address the ambiguity in QFD process. The QFD process contains four phases. The house of quality matrix is often called as the phase one matrix, or the planning matrix (Hauser & Clausing, 1988) that is shown in Fig. 1 (a). Its process, following approaches suggested by Brown (1991), and Griffin and Hauser (1992) are given in Fig. 1 (b).

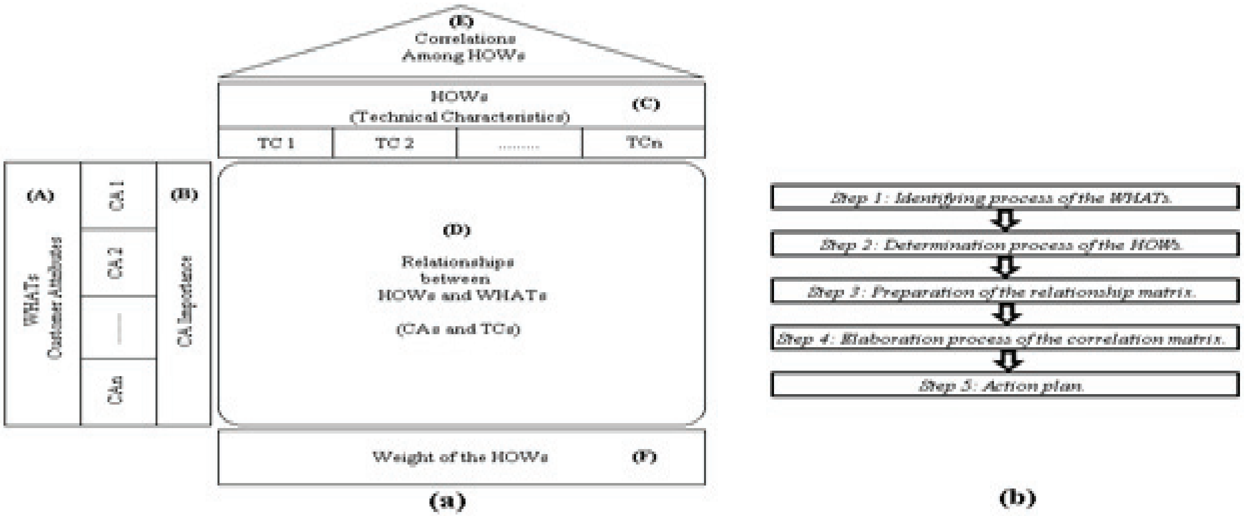


Figure 1. House of quality and its process

3.3. Defuzzification Method

In this paper, the CFCS (Converting Fuzzy data into Crisp Scores) defuzzification method, which was first proposed by Opricovic and Tzeng (2003), is employed through fuzzy aggregation procedure. If $\widetilde{z}_{ij}^{d} = (\alpha_{ij}^{d}, \beta_{ij}^{d}, \gamma_{ij}^{d})$ is given for the fuzzy evaluations 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 is given in Fig. 2.

(1) Normalization:

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

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

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

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

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

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

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

(3) Compute total normalized crisp value:

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

(4) Compute crisp values

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

(5) Integrate crisp values:

$$z_{ij} = \frac{1}{p}(z_{ij}^{1} + z_{ij}^{2} + \cdots + z_{ij}^{p}).$$

Figure 2. CFCS Deffuzzification steps

4. Application – Identification of Key Factors for an Online Education Website

4.1. Selection of the decision-makers

In this study, most of the decision-makers are managers/executives of e-learning providers and e-learning users at the institutional level. 18 individuals were selected and sent the invitations to participate in this research, 6 sent feedback.

4.2. Determining the linguistic terms and corresponding fuzzy numbers

The linguistic variables in Table 1 [Very High (8;9;10), High (6;7;8), Medium (4;5;6), Low (2;3;4) and Very Low (0;1;2)] are used to aggregate each decision-makers' opinions.

To select the quality characteristics to be used in this research, attributes were summarized after undertaking a wide-ranging literature review (Waters, 1996; Brajnik, 2001; Mich et al., 2003; Calero et al., 2005; Zhou et al., 2008; Li et al., 2009). After the decision-makers' evaluation, 10 attributes are identified and shown in Table 2 (a).

4.4. Identifying HOWs

In this step, as mentioned above, the limitations and specific characteristics of e-learning productions were reviewed by scanning literature. HOWs were identified according to the e-learning systems providers' capabilities to meet customer attributes. Identified HOWs by each decision-maker are given in Table 2 (b).

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

4.5. Calculating the importance degrees of WHATs

To calculate the degree of importance for each WHAT, each decision-maker are asked to use the linguistic variables given in order to evaluate the degree of importance for each WHAT. After collecting the results, the geometric mean method for each decision-makers' evaluations was employed to calculate the fuzzy weights for WHATs. The importance degrees of WHATs are shown in Fig. 3.

4.6. Identifying the correlation between HOWs and WHATs

In this step, each decision-maker was asked to evaluate the impact of each HOW on each WHAT. In order to express their opinions, each decision-maker used the linguistic variables in Table 1 again. The results of the evaluation are given in Fig. 3.

4.7. Computing the weights of HOWs

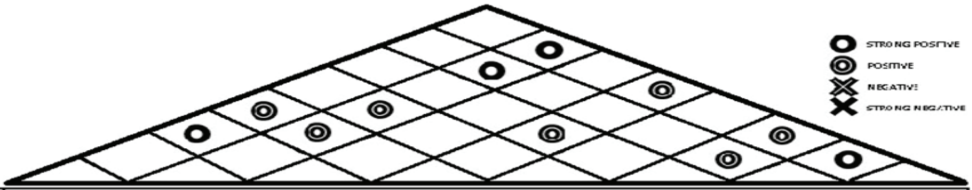
In order to rank HOWs, calculation of weights of HOWs is needed. By using Eq. (1) on the triangular fuzzy numbers, weights of each HOWs (W_i) are calculated. The result of calculation is shown in Fig. 3.

$$Weight(TC)i = V(TC)i1 \times Im(CA1) + \ldots + V(TC)in \times Im(CAn), \quad (1)$$

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

4.8. Measuring the correlation of HOWs

This step of HOQ provides the information about the specification of relationship among HOWs for e-learning system providers, especially the design team members of e-learning systems. In order to measure the relationship among each HOW, symbols that show direction and strength of the relationships are determined. "Strongly Positive", "Positive", "Negative" and "Strongly Negative" are symbolized in Fig. 3. Then, each decision-maker was asked to evaluate positive and negative correlation between pairs of HOWs. The results are shown in the roof matrix of the HOQ in Fig. 3.



WHATs	α	β	γ	HOWs: CE α	CE β	CE γ	TC α	TC β	TC γ
AE	4,67	5,67	6,67	2,33	2,83	3,33	3,33	3,83	4,33
FC	4,00	5,00	6,00	0,33	0,83	1,33	2,67	3,17	3,67
RL	5,33	6,33	7,33	1,67	2,17	2,67	1,67	2,17	2,67
US	2,33	3,33	4,33	3,00	3,50	4,00	1,67	2,17	2,67
EF	4,00	5,00	6,00	2,33	2,83	3,33	2,33	2,83	3,33
MT	5,33	6,33	7,33	2,67	3,17	3,67	2,00	2,50	3,00
PR	6,00	7,00	8,00	1,00	1,50	2,00	3,00	3,50	4,00
RC	5,67	6,67	7,67	2,67	3,17	3,67	2,33	2,83	3,33
CS	5,33	6,33	7,33	2,33	2,83	3,33	2,00	2,50	3,00
CT	5,33	6,33	7,33	2,67	3,17	3,67	3,33	3,83	4,33
				W1			W2		
				9,94	14,94	20,94	11,87	17,20	23,53

WHATs	QC α	QC β	QC γ	RP α	RP β	RP γ	FS α	FS β	FS γ
AE	3,67	4,17	4,67	3,33	3,83	4,33	3,67	4,17	4,67
FC	0,67	1,17	1,67	2,67	3,17	3,67	0,67	1,17	1,67
RL	1,00	1,50	2,00	0,33	0,83	1,33	3,33	3,83	4,33
US	1,33	1,83	2,33	2,00	2,50	3,00	2,33	2,83	3,33
EF	2,67	3,17	3,67	2,33	2,83	3,33	2,67	3,17	3,67
MT	2,33	2,83	3,33	2,00	2,50	3,00	2,33	2,83	3,33
PR	3,67	4,17	4,67	2,67	3,17	3,67	3,00	3,50	4,00
RC	1,00	1,50	2,00	2,67	3,17	3,67	1,33	1,83	2,33
CS	2,00	2,50	3,00	1,67	2,17	2,67	1,00	1,50	2,00
CT	2,67	3,17	3,67	1,33	1,83	2,33	2,33	2,83	3,33
	W3			W4			W5		
	10,39	15,39	21,39	9,98	14,98	20,98	10,94	16,11	22,28

WHATs	EI α	EI β	EI γ	QDT α	QDT β	QDT γ	QSS α	QSS β	QSS γ
AE	3,33	3,83	4,33	3,67	4,17	4,67	3,33	3,83	4,33
FC	3,33	3,83	4,33	1,33	1,83	2,33	2,33	2,83	3,33
RL	2,67	3,17	3,67	1,67	2,17	2,67	1,67	2,17	2,67
US	1,67	2,17	2,67	2,33	2,83	3,33	1,67	2,17	2,67
EF	2,00	2,50	3,00	3,33	3,83	4,33	2,33	2,83	3,33
MT	2,00	2,50	3,00	3,00	3,50	4,00	2,00	2,50	3,00
PR	1,67	2,17	2,67	3,00	3,50	4,00	2,33	2,83	3,33
RC	2,33	2,83	3,33	2,33	2,83	3,33	3,67	4,17	4,67
CS	1,67	2,17	2,67	2,33	2,83	3,33	3,33	3,83	4,33
CT	2,67	3,17	3,67	3,33	3,83	4,33	3,33	3,83	4,33
	W6			W7			W8		
	11,20	16,43	22,67	12,76	18,29	24,82	12,80	18,30	24,80

Figure 3. The fuzzy – house of quality

4.9. Converting fuzzy weights to crisp scores for ranking each HOW

CFCS defuzzification method is employed to defuzzify each weight of HOWs using equations in Fig. 2. Following this, crisp values are ranked from the highest to the lowest score. The scores and ranks are shown in Table 3.

Table 3. Scores and ranks of HOWs

HOWs	Score	Ranking	HOWs	Score	Ranking
QSS	18,34	1	FS	16,42	5
QDT	18,33	2	QC	15,77	6
TC	17,38	3	RP	15,41	7
EI	16,71	4	CE	15,38	8

5. Discussions and Conclusions

By using fuzzy logic-based QFD, key factors can be identified for a successful e-learning design. It also helps to see the capabilities of e-learning providers in order to meet customer demand. Identification of WHATs is another important outcome. This can help e-learning providers to improve their specifications to enable the creation of more customer-oriented e-learning services. This framework may also provide a way of choosing the most suitable provider for specific firms and the institutions. In the future, this model may be used for selection of e-learning providers. According to the final results, "Qualified Support Service Staff" has the highest score and is thus identified as the most important factor, followed key is "Qualified and/or Experienced Design Team" and "Technical Capability", and "Experience in the Industry", respectively. These four factors have relatively higher scores than the others including "Financial Stability" "Quality Certification", "Reputation" and "Certificated Education". It also indicates that human resources are among the most important features of the online education industry. Therefore, it can be concluded that a balance of human resources and technological factors are needed for successful e-learning design.

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