An Approach to Academic Library Service Quality Evaluation Based on Fuzzy Linguistic Quantifier

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***Abstract*—Service activities are the fundamental and dominant factors of the library and the significance and influence of service quality have been recognized through the great effect on satisfaction of consumer. In this paper, the assessments of consumers are described by linguistic terms which can be expressed in fuzzy variable, and a fuzzy multiple attribute decision making method based on the fuzzy linguistic quantifier is proposed to deal with the problem of academic library service quality evaluation. Case study is provided to illustrate the implementation and effectiveness of the method.**

***Keywords*-service quality evaluation; fuzzy linguistic quantifier; fuzzy variable; fuzzy simulation**

I. INTRODUCTION

Service is an essential component for an academic library. In academic library environments, it is important to examine what users need and desire for services. Service activities are the fundamental and dominant factors of the library and the significance and influence of service quality have been recognized through the great effect on satisfaction of consumers. The academic library service quality evaluation is a multiple attribute decision making problem. It is engineering and management decision aid in evaluating library service quality which is characterized by multiple attributes. Usually, consumers express their opinions by means of numerical values. When consumers are not able to give exact numerical value to evaluate library service quality, a more realistic alternative option is using linguistic assessments instead of numerical values. In such a situation, for each attribute in the problem domain, some appropriate linguistic labels such as good, medium, poor etc are chosen and used by individuals who participate in the library service quality evaluation to express their opinions. Therefore, it involves vagueness and fuzziness in the process of evaluation on academic library service quality. The vagueness and fuzziness comes from a variety of sources such as incomplete information, or fuzzy understanding of situations by consumers. The academic library service quality evaluation is a multiple attributive decision making in a fuzzy environment.

The classical multiple attribute decision making methods cannot effectively handle problems with such imprecise information. Fuzzy set theory by Zadeh [1] in 1965, is a powerful tool to handle the problem of linguistic terms which can be expressed in fuzzy numbers. Bellman and Zadeh [2] proposed the fuzzy decision making model in 1970. Since then, many investigators such as Baas and Kwakernaak [3], Yager [4], [5], Chen [6], Aouam, Chang and Lee [7], among many others, have proposed approaches to handle multiple attributive decision making problems involve imprecise data and fuzzy expressions that are more natural for humans than rigid mathematical rules and equations.

Based on fuzzy set theory, the above methods make best use of multiple attributive decision making in a fuzzy environment. However, the linguistic terms are characterized as fuzzy numbers can not be easily calculated. Recently, Liu and Liu [8] defined a credibility measure and gave an expected value operator of fuzzy variable. Moreover, with fuzzy simulation technic, the utility for each attribute can be expressed by a real-value function. In this paper, the approach for academic library service quality evaluation in which linguistic terms are characterized as fuzzy variables is presented.

In summary, this paper is organized as follows. Section 2 discusses some of the basic concepts related with fuzzy variable relevant to the paper. Section 3 then presents an academic library service quality evaluation method. In section 4, a case study is provided to demonstrate the effectiveness of the proposed approach. The last section presents the concluding remarks.

II. FUZZY VARIABLE

Let ξ be a fuzzy variable with membership function μ, and u and r be a real number. The possibility of a fuzzy event, characterized by $\{\xi \leq r\}$, is defined by $\mathrm{Pos}\{\xi \leq r\} = \sup_{u \leq r} \mu(u)$. While the credibility of a fuzzy event, characterized by $\{\xi \leq r\}$, is defined by $\mathrm{Cr}\{\xi \geq r\} = \frac{1}{2}(\mathrm{Pos}\{\xi \geq r\} + 1 - \mathrm{Pos}\{\xi < r\})$.

Definition 1: (Liu and Liu [8]) Let ξ be a fuzzy variable on the possibility space $(\Theta, P(\Theta), \mathrm{Pos})$, the expected value $E[\xi]$ is defined by

$$E[\xi] = \int_0^{+\infty} \mathrm{Cr}\{\xi \geq r\}\mathrm{d}r - \int_{-\infty}^{0} \mathrm{Cr}\{\xi \leq r\}\mathrm{d}r$$

provided that at least one of the two integrals is finite.

Definition 2: (Liu [9]) The fuzzy variables $\xi_1, \xi_2, \cdots, \xi_n$ are said to be independent if and only if

$$\mathrm{Pos}\{\xi_i \in \mathcal{A}_i \;\; i = 1, 2, \cdots, n\} = \min_{1 \leq i \leq n} \mathrm{Pos}\{\xi_i \in \mathcal{A}_i\}$$

for any sets $\mathcal{A}_1, \mathcal{A}_2, \cdots, \mathcal{A}_n$ of $\Re$.

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Theorem 1: (Liu [9]) Let that ξ and η be independent fuzzy variables with finite expected values. For any real numbers a and b, we have

$$E[a\xi + b\eta] = aE[\xi] + bE[\eta].$$

III. An Academic Library Service Quality Evaluation Approach

Let $\xi = (\xi_1, \xi_2, \cdots, \xi_k)$ be a set of performance rating and $A = (A_1, A_2, \cdots, A_n)$ be a finite set of attributes. $V = (v_1, v_2 \cdots, v_n)$ is the set of weights of attributes and $R = \{R_{ij} \mid i = 1, 2, v_2 \cdots, n; j = 1, 2, v_2 \cdots, k\}$ is a $N \times K$ decision matrix, where R_{ij} is the number of individual of performance rating ξ_j with respect to attribute A_i. The academic library service quality evaluation can be expressed in matrix as follow:

$$\begin{pmatrix} R_{11} & R_{12} & \cdots & R_{1k} \\ R_{21} & R_{22} & \cdots & R_{2k} \\ \vdots & \vdots & \ddots & \vdots \\ R_{n1} & R_{n2} & \cdots & R_{nk} \end{pmatrix},$$

where $\sum_{j=1}^{k} R_{ij} = M$.

The procedure of a academic library service quality evaluation approach based on fuzzy linguistic quantifier is summarized as follow.

Step 1: Generating aspects for attributes.

In order to promote content quality, the selected attributes and sub-attributes must be discussed with experts and consumers in the college. The evaluation criteria developed by several researches [10], [11]. The assessing aspect information of LibQUAL+^{TM} [12] is adopted from the evaluation plan for academic library service quality evaluation. LibQUAL+^{TM} is a tool designed to measure user perceptions of service quality in academic libraries.

Step 2: Determination of weights of attributes.

Since human's thought process cannot directly determine the weight value, He or she can describe by language and balance its importance corresponding to attribute, and the weight comes from the language. Analytic hierarchy process proposed by Saaty [13], [14] is a decision aid to help solve this problem. In analytic hierarchy processthe pairwise comparisons, which reflect the relative importance among attributes themselves, must be elicited from the domain expert or consensus from several people's judgment. Saaty made a series of pairwise comparisons among the elements according to a ratio scale 1, 3, 5, 7 and 9, and used the eigenvalue method to estimate the relative weights of the elements. He aggregate these relative weights and synthesize them for the final measurement. More detail on analytic hierarchy process can be found in [13], [14]. In this paper, we use the analytic hierarchy process to determine weights of attributes.

Step 3: Rating state.

In this state, evaluation of the questionnaires are distributed to consumers. Each consumer gives his/her opinions (or performance ratings) about each attribute. These ratings are generally in fuzzy data form. The fuzzy data are linguistic terms such as good, important, poor, middle etc.

Step 4: Converting fuzzy data to fuzzy variables.

This state aims to convert fuzzy data into standardized triangular fuzzy variables. Based on [8], [15], fuzzy variables are used to denote the qualitative assessments of attributes. Five triangular fuzzy variables $\xi_1 = (0.00, 0.00, 0.20)$, $\xi_2 = (0.05, 0.25, 0.45)$, $\xi_3 = (0.30, 0.50, 0.70)$, $\xi_4 = (0.55, 0.75, 0.95)$, $\xi_5 = (0.80, 1.00, 1.00)$ represent the five linguistic values. For instance: very poor, poor, middle, good, very good, respective etc.

Step 5: Based on $\xi = (\xi_1, \xi_2, \cdots, \xi_5)^T$ and R, the fuzzy evaluation of each attribute $U = (U_1, U_2, \cdots, U_n)^T$ can be obtained.

$$\begin{pmatrix} U_1 \\ U_2 \\ \vdots \\ U_n \end{pmatrix} = \frac{1}{M} \begin{pmatrix} R_{11} & R_{12} & \cdots & R_{15} \\ R_{21} & R_{22} & \cdots & R_{25} \\ \vdots & \vdots & \ddots & \vdots \\ R_{n1} & R_{n2} & \cdots & R_{n5} \end{pmatrix} \begin{pmatrix} \xi_1 \\ \xi_2 \\ \vdots \\ \xi_5 \end{pmatrix}.$$

Step 6: Based on $U = (U_1, U_2, \cdots, U_n)^T$ and the set of weights of attributes $V = (V_1, V_2 \cdots, V_n)^T$, we have the fuzzy evaluation of academic library service quality.

$$e = (U_1, U_2, \cdots U_n)(V_1, V_2, \cdots V_n)^T.$$

Step 7: The defuzzification value of the fuzzy evaluation of academic library service quality.

With the expected value operator for fuzzy variables presented by Liu and Liu [8], the utility for the fuzzy evaluation can be expressed by a real valued function. By using the fuzzy simulation method, the crisp evaluation value of attribute $E[f(\boldsymbol{\xi})]$ can be obtained. The fuzzy simulation method for estimating $E[f(\boldsymbol{\xi})]$ is described as follows.

1) Set l = 0.
2) Generate randomly θ_k from Θ such that $\mathrm{Pos}\{\theta_k\} \geq \varepsilon$ and set $v_k = \mathrm{Pos}\{\theta_k\}$ for $k = 1, 2, \cdots, N$, where ε is a sufficiently small number.
3) Set $a = f(\boldsymbol{\xi}(\theta_1)) \wedge \cdots \wedge f(\boldsymbol{\xi}(\theta_N)), b = f(\boldsymbol{\xi}(\theta_1)) \vee \cdots \vee f(\boldsymbol{\xi}(\theta_N))$.
4) Generate randomly r from $[a, b]$.
5) If $r \geq 0$, then $l \leftarrow l + \mathrm{Cr}\{f(\boldsymbol{\xi}) \geq r\}$, where
$$\mathrm{Cr}\{f(\boldsymbol{\xi}) \geq r\} = \frac{1}{2} \max_{1 \leq k \leq N} \{v_k \mid f(\boldsymbol{\xi}(\theta_k)) \geq r\} + \frac{1}{2} \min_{1 \leq k \leq N} \{1 - v_k \mid f(\boldsymbol{\xi}(\theta_k)) < r\}.$$
6) If $r < 0$, then $l \leftarrow l - \mathrm{Cr}\{f(\boldsymbol{\xi}) \leq r\}$, where
$$\mathrm{Cr}\{f(\boldsymbol{\xi}) \leq r\} = \frac{1}{2} \max_{1 \leq k \leq N} \{v_k \mid f(\boldsymbol{\xi}(\theta_k)) \leq r\} + \frac{1}{2} \min_{1 \leq k \leq N} \{1 - v_k \mid f(\boldsymbol{\xi}(\theta_k)) > r\}.$$
7) Repeat the steps from 4) to 6) for N times.
8) Computing $E[f(\boldsymbol{\xi})] = a \vee 0 + b \wedge 0 + l \cdot (b - a)/N$.

The fuzzy simulation technique is an effective tool to evaluate $E[f(\xi)]$. More detail on fuzzy simulation can be found in [8], [16], [17].

IV. CASE STUDY

In this case study, we adopt LibQUAL+^{TM} [12] 2004 dimensions. The attributes below are those used in the college implementation of the survey.

In light of the present attributes of the academic library service quality evaluation according to LibQUAL+^{TM} [12] 2004, Affect of Service F, Information Control S, Library as Place T are the primary attributes.

The first primary attribute is decomposed into nine secondary attributes:

(1) F_1: Employees who instill confidence in users,

(2) F_2: Giving users individual attention,

(3) F_3: Employees who are consistently courteous,

(4) F_4: Readiness to respond to users' questions,

(5) F_5: Employees who have the knowledge to answer user questions,

(6) F_6: Employees who deal with users in a caring fashion,

(7) F_7: Employees who understand the needs of their users,

(8) F_8: Willingness to help users,

(9) F_9: Dependability in handling users service problems.

The second primary attribute is decomposed into eight secondary attributes:

(1) S_1: Making electronic resources accessible from my home or office,

(2) S_2: A library Web site enabling me to locate information on my own,

(3) S_3: The printed library materials I need for my work,

(4) S_4: The electronic information resources I need,

(5) S_5: Modern equipment that lets me easily access needed information,

(6) S_6: Easy-to-use access tools that allow me to find things on my own,

(7) S_7: Making information easily accessible for independent use,

(8) S_8:Print and/or electronic journal collections I require for my work.

The third primary attribute is decomposed into five secondary attributes:

(1) T_1;Library space that inspires study and learning,

(2) T_2: Quiet space for individual activities,

(3) T_3: A comfortable and inviting location,

(4) T_4: A getaway for study, learning or research,

(5) T_5: Community space for group learning and group study.

Based on the consensus from several expert's judgment, the pairwise comparisons matrix of the primary attributes as follows: $\begin{pmatrix} 1 & 0.5 & 3 \\ 2 & 1 & 5 \\ 0.33 & 0.2 & 1 \end{pmatrix}$. According to the matrix, $\lambda_{max} = 3.004, CI = 0.002, RI = 0.580, CR = 0.003, CR < 0.001$, and weights of the primary attributes are $(0.309, 0.582, 0.109)$.

Table I
THE WEIGHTS OF SECONDARY ATTRIBUTES

Attribute	Weight	Attribute	Weight
F_1	0.164	S_3	0.214
F_2	0.057	S_4	0.214
F_3	0.032	S_5	0.071
F_4	0.165	S_6	0.071
F_5	0.165	S_7	0.071
F_6	0.032	S_8	0.215
F_7	0.165	T_1	0.387
F_8	0.057	T_2	0.212
F_9	0.165	T_3	0.069
S_1	0.071	T_4	0.213
S_2	0.071	T_5	0.119

The pairwise comparisons matrix of nine secondary attributes of the first primary attribute is given by

$$\begin{pmatrix} 1 & 3 & 5 & 1 & 1 & 5 & 1 & 3 & 1 \\ 0.33 & 1 & 2 & 0.33 & 0.33 & 2 & 0.33 & 1 & 0.33 \\ 0.2 & 0.5 & 1 & 0.2 & 0.2 & 1 & 0.2 & 0.5 & 0.2 \\ 1 & 3 & 5 & 1 & 1 & 5 & 1 & 3 & 1 \\ 1 & 3 & 5 & 1 & 1 & 5 & 1 & 3 & 1 \\ 0.2 & 0.5 & 1 & 0.2 & 0.2 & 1 & 0.2 & 0.5 & 0.2 \\ 1 & 3 & 5 & 1 & 1 & 5 & 1 & 3 & 1 \\ 0.33 & 1 & 2 & 0.33 & 0.33 & 2 & 0.33 & 1 & 0.33 \\ 1 & 3 & 5 & 1 & 1 & 5 & 1 & 3 & 1 \end{pmatrix}.$$

The pairwise comparisons matrixes of eight secondary attributes of the second primary attribute and fives secondary attributes of the third primary attribute are given by

$$\begin{pmatrix} 1 & 1 & 0.33 & 0.33 & 1 & 1 & 1 & 0.33 \\ 1 & 1 & 0.33 & 0.33 & 1 & 1 & 1 & 0.33 \\ 3 & 3 & 1 & 1 & 3 & 3 & 3 & 1 \\ 3 & 3 & 1 & 1 & 3 & 3 & 3 & 1 \\ 1 & 1 & 0.33 & 0.33 & 1 & 1 & 1 & 0.33 \\ 1 & 1 & 0.33 & 0.33 & 1 & 1 & 1 & 0.33 \\ 1 & 1 & 0.33 & 0.33 & 1 & 1 & 1 & 0.33 \\ 3 & 3 & 1 & 1 & 3 & 3 & 3 & 1 \end{pmatrix},$$

and

$$\begin{pmatrix} 1 & 2 & 5 & 2 & 3 \\ 0.5 & 1 & 3 & 1 & 2 \\ 0.2 & 0.33 & 1 & 0.33 & 0.5 \\ 0.5 & 1 & 3 & 1 & 2 \\ 0.33 & 0.5 & 2 & 0.5 & 1 \end{pmatrix}.$$

The weights of secondary attributes are listed in Table I.

The number of evaluation of the questionnaires distributed to consumers is 300. The consumers are asked to use the following scale for the rating: very poor, poor, middle,good, and very good. The available number of questionnaires retrieved is 272. The available number of individual of performance rating with respect to twenty two secondary attributes are shown in Table II.

We can get the fuzzy evaluation Library as Place T according to $e_T = (U_{T1}, U_{T2}, \cdots U_{T5})(V_{T1}, V_{T2}, \cdots V_{T5})^T$. $V_T =$

Table II
THE AVAILABLE NUMBER OF PERFORMANCE RATING

	very poor (ξ_1)	poor (ξ_2)	middle (ξ_3)	good (ξ_4)	very good (ξ_5)
F_1	1	2	25	202	42
F_2	0	3	55	166	48
F_3	0	1	50	174	47
F_4	0	2	57	169	44
F_5	0	2	45	175	50
F_6	0	1	67	162	42
F_7	0	1	43	186	42
F_8	1	2	43	176	50
F_9	0	3	42	186	41
S_1	1	22	23	162	64
S_2	0	8	40	146	78
S_3	0	19	54	130	69
S_4	2	2	57	143	68
S_5	3	2	40	155	72
S_6	2	11	47	140	72
S_7	0	6	37	161	68
S_8	0	3	43	156	70
T_1	0	25	35	160	52
T_2	0	18	43	153	58
T_3	0	23	45	152	52
T_4	0	22	52	149	49
T_5	0	29	47	145	51

$(V_{T1}, V_{T2}, \cdots V_{T5})^T$ can be obtained according to Table I, and $V_T = (0.387, 0.212, 0.069, 0.213, 0.119)$. $U_T = (U_{T1}, U_{T2}, U_{T3}, U_{T4}, U_{T5})^T$can be obtained according to Table II,

$$U_T = (U_{T1}, U_{T2}, U_{T3}, U_{T4}, U_{T5})^T = \frac{1}{272}\begin{pmatrix} 0 & 25 & 35 & 160 & 52 \\ 0 & 18 & 43 & 153 & 58 \\ 0 & 23 & 45 & 152 & 52 \\ 0 & 22 & 52 & 149 & 49 \\ 0 & 29 & 47 & 145 & 51 \end{pmatrix}\begin{pmatrix} (0.00, 0.00, 0.20) \\ (0.05, 0.25, 0.45) \\ (0.30, 0.50, 0.70) \\ (0.55, 0.75, 0.95) \\ (0.80, 1.00, 1.00) \end{pmatrix}$$

By 2000 sample points in fuzzy simulation, the expect value of fuzzy evaluation $E[e_T] = 0.7047$. Similarly, the evaluation for Affect of Service $E[e_F]$ and Information Control $E[e_S]$ can be obtained. The the expect values of fuzzy evaluation are $E[e_F] = 0.7355$, and $E[e_S] = 0.7430$. Based on weights of primary attributes $(0.309, 0.582, 0.109)$, the academic library service quality evaluation is 0.7365.

V. CONCLUSION

This paper proposed a new approach to solve the problem of academic library service quality evaluation. In this method, the consumers' opinions are described by linguistic terms that can be expressed in fuzzy variables and fuzzy simulation is applied to calculate the fuzzy expect value. A real evaluation on academic library service quality case study has been carried out, and the case demonstrates the efficiency and practicability of the approach. The proposed method provides a new idea for education department to evaluate the academic library service quality. The proposed method is easy to understand and is a generalized model, which can be applied to great variety of practical problems which contain the fuzzy data.

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