EVALUATION OF LIBRARY SERVICES USING FUZZY APPROACH

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***Abstract*—Library is one of the important departments in academic institutions that enable the exchange and growth of information, knowledge, and culture among lecturers, students, and the general public. The important thing about the library is quality services. Service quality of library consists of some attributes such as physical facilities and staff behaviors. Evaluation of quality services may help library management to ensure the improvement of services by investigating students' opinion towards library services. The objective of this research is to evaluate the quality of services provided by the library based on certain criteria using Fuzzy Multi-Criteria Decision Making (MCDM) evaluation method. A fuzzy logic method is used to deal with the decision in the ambiguous situation. A research was conducted at Perpustakaan Al Bukhari in Universiti Teknologi MARA (Pahang). A questionnaire has been used to collect the data. Respondents were students who came to the library four times a week. Result stated that the best criterion is staff service while the worst is the environment at the library.**

Keywords-Library Services, Service Quality, Fuzzy Multi-Criteria Decision Making, Linguistic terms.

I. INTRODUCTION

Academic institution usually attached with libraries which play a role to fulfill the teaching and research needs of students and staff [1]. According to [10] the objective for a library is to improve library service with fulfilling the user requirements. Based on [2], the goal for a library is to maintain the service quality and satisfy the users. There are a few criteria to evaluate service quality such as leadership, resources, physical facilities and staff behavior [12]. Service quality can be recognized by customer loyalty and their feedback about satisfaction based on [9]. In this research, library services isare evaluated by using fuzzy Multiple Criteria Decision Making (MCDM). The best evaluator for service quality in a library is the users that came to the library [4].

This research proposed fuzzy evaluation method in evaluating library service. Fuzzy logic is a useful method to deal with the decision in an ambiguous situation [6]. According to [7] using fuzzy MCDM would avoid bias and minimize partiality. Based on [13], quality services must have a fuzzy linguistic technique to create a user-friendly framework. MCDM method must have a decision maker to judge the quality services for qualitative criteria rating and the weight of criteria. However, rating and weight in library services are difficult to characterize because of the existence of uncertainty, but it can be easily evaluated if a linguistic term is used. Linguistic quality rating is combining linguistic evaluation judgments from the customer on the different criteria [13]. Fuzzy decision making has been expanded from traditional MCDM method where linguistic term always been used to solve the fuzzy MCDM problem [15]. Linguistic terms enhance after modeled by fuzzy numbers, like triangular fuzzy number [8]. Thus, linguistic term is one of the solutions for MCDM method since it can compute the evaluation without specific number but in variables such as very low, low, medium low, medium until very high.

This study was conducted to evaluate the quality of services provided by library based on certain criteria using fuzzy evaluation method. This research uses MCDM to evaluate the quality services. The fuzzy evaluation is one of the methods to the ambiguous problem. Therefore, fuzzy MCDM is the best way to evaluate the service quality because it uses respondents. This research has been done at Perpustakaan Al-Bukhari UiTM Pahang. 93 respondents who were selected randomly answered this questionnaire which is more than 30 percent of the visitors for a week.

II. PRELIMINARIES

The basic definition of a fuzzy number and its operations on triangular fuzzy numbers are given as follows.

A. Fuzzy Number

A fuzzy number is a fuzzy subset of the universe of discourse that is both convex and normal. The

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membership function of a fuzzy number A can be defined as

$$f_A(x)=\begin{cases} f_A^L & , \quad a \le x \le b \\ 1 & , \quad b \le x \le c \\ f_A^R & , \quad c \le x \le d \\ 0 & , \quad otherwise \end{cases} \qquad (1)$$

where $f_A^L:[a,b]\to[0,1]$, $f_A^R:[c,d]\to[0,1]$, f_A^L and f_A^R are the left and right membership function of the fuzzy number *A* respectively. Trapezoidal fuzzy numbers are denoted as *(a,b,c,d)* and triangular fuzzy number which are special cases of trapezoidal fuzzy numbers with *b=c* are denoted as *(a,b,d)*.

B. Operations on Triangular Fuzzy Numbers

Let *X* and *Y* be two triangular fuzzy numbers parameterized by (x_1, x_2, x_3) and (y_1, y_2, y_3) respectively. The fuzzy number arithmetic operations *X* and *Y* are presented as follows:

Addition operation:

$$X \oplus Y = (x_1 + y_1, x_2 + y_2, x_3 + y_3) \qquad (2)$$

Subtraction operation:

$$X - Y = (x_1 - y_3, x_2 - y_2, x_3 - y_1) \qquad (3)$$

where x_1, x_2, x_3, y_1, y_2 and y_3 are real numbers.

Multiplication operation:

$$X \otimes Y = (x_1 y_1, x_2 y_2, x_3 y_3) \qquad (4)$$

Division operation:

$$X / Y = (x_1 / y_3, x_2 / y_2, x_3 / y_1) \qquad (5)$$

where x_1, x_2, x_3, y_1, y_2 and y_3 are real numbers.

III. PROPOSED METHOD

Questionnaires were given to 10 respondents who are the respondents that use the library services. It used two sets of fuzzy linguistic terms to evaluate the importance levels of each criterion and the satisfaction levels of each sub-criterion. The linguistic terms can be expressed as trapezoidal fuzzy numbers as in Table I and Table II.

TABLE I. LINGUISTIC TERMS FOR IMPORTANCE WEIGHTS [3]

Linguistic terms	Fuzzy Numbers
Very Low	(0,0,0.1)
Low	(0,0.1,0.3)
Medium Low	(0.1,0.3,0.5)
Medium	(0.3,0.5,0.7)
Medium High	(0.5,0.7,0.9)
High	(0.7,0.9,1)
Very High	(0.9,1,1)

TABLE II. LINGUISTIC TERMS FOR SATISFACTION RATING [3]

Linguistic terms	Fuzzy numbers
Very Poor	(0,0,1)
Poor	(0,1,3)
Medium Poor	(1,3,5)
Fair	(3,5,7)
Medium Good	(5,7,9)
Good	(7,9,10)
Very Good	(9,10,10)

The procedure of the fuzzy evaluation can be explained into several steps. Procedures for Step 1 until Step 6 were based on [11]. The procedure is:

Step 1:

For K respondents, the fuzzy weight w_i, of each criterion, i is calculated using aggregated fuzzy assessment which is defined as

$$w_i = \frac{\sum_{k=1}^{K} w_i^k}{K} \qquad (6)$$

where w_i^k is the importance weight of the *k*-th decision maker. The fuzzy weighted vector criteria can be represented $W = [w_1 \quad w_2 \quad \dots \quad w_i]^T$.

Step 2:

The fuzzy rating r_{ij}, of each alternative is calculated using aggregated fuzzy assessment which is defined as

$$r_{ij} = \frac{\sum_{k=1}^{K} x_{ij}^k}{K} \qquad (7)$$

where x_{ij}^k is the satisfaction rating of the *k*-th decision maker for *i*-th criterion and *j*-th sub-criterion.

Step 3:

The fuzzy grade g_{ij}, of each criterion is calculated using aggregated fuzzy assessment which is defined as

$$g_{ij} = \frac{\sum_{i=1, j=1}^{i=m, j=n} r_{ij}^k}{j} \qquad (8)$$

where criterion, i is $i=1,2,...,m$ and sub-criterion, j is $j=1,2,...,n$.

Step 4:

The fuzzy grade matrix *G* is build and defined as

$$G = \begin{pmatrix} g_{11} & g_{12} & \cdots & g_{1k} \\ g_{21} & g_{22} & \cdots & g_{2k} \\ \vdots & \vdots & \ddots & \vdots \\ g_{n1} & g_{n2} & \cdots & g_{nk} \end{pmatrix} \quad (9)$$

where g_{ij} denotes the fuzzy grade of the *i*-th alternative A_i with respect to the *j*-th criterion X_j, *n* denotes the number of alternative and *k* denotes the number of criteria.

Step 5:
The total fuzzy grade vector *R* is calculated as

$$R = G \otimes W = \begin{pmatrix} R_1 \\ R_2 \\ \vdots \\ R_k \end{pmatrix} \quad (10)$$

where R_i denotes the total fuzzy grade of the *i*-th alternative A_i and $1 \le i \le n$.

Step 6:
The ranking order of *R* is calculated based on Wang et al. (2006) method of centroid point corresponding to a value of $\bar{x}$ defined as

$$\bar{x}(R_i) = \frac{\int_a^b x f_R^1 dx + \int_b^c x f_r^R dx}{\int_a^b f_R^1 dx + \int_b^c f_R^r dx} \quad (11)$$

where f_R^1 and f_R^r are right and left membership function of R_i respectively.

This proposed method is implemented to the evaluation of library services as shown by the hierarchical structure in Figure 1. The evaluation criteria are taken from [11] and [5].

IV. Fuzzy Evaluation of Library Services

The evaluation was done through a questionnaire that contains 16 criteria regarding the library services. The questionnaires were divided into four parts which are the environment of the library, information about the library, internet access, and staff services. The required data were gathered in the form of a questionnaire asking the respondents to choose the importance of the mentioned indicators based on linguistic terms taken from [3]. The hierarchical structure of service evaluation is shown in Figure 1.

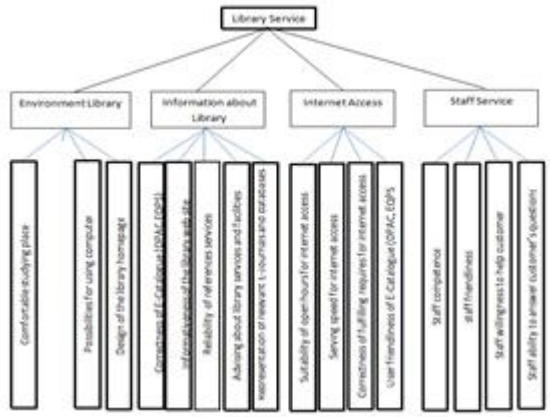

Fig. 1: The hierarchical structure of the service

Two sets of fuzzy linguistic terms used to evaluate the importance levels of each criterion and the satisfaction levels of each sub-criterion are distributed to the respondents. The data analyzed by fuzzy evaluation method. For the written description, data represent only for 10 respondents. Table III shows the importance weight, and Table IV shows the satisfaction ratings evaluate by respondents.

TABLE III. IMPORTANCE LEVEL OF CRITERIA BY THE RESPONDENTS

Criteria	Respondents									
	K_1	K_2	K_3	K_4	K_5	K_6	K_7	K_8	K_9	K_{10}
X_1	H	VH	H	VH	H	VH	H	VH	VH	MH
X_2	MH	VH	VH	VH	H	VH	ML	H	MH	M
X_3	MH	H	H	VH	H	MH	H	ML	L	VL
X_4	H	VH	VH	VH	H	VH	H	VH	H	H

TABLE IV. SATISFACTION LEVEL OF LIBRARY EVALUATION BY EACH RESPONDENT

Criteria	Sub-criteria	Respondents									
		K1	K2	K3	K4	K5	K6	K7	K8	K9	K10
X_1	X_{11}	G	VG	VG	G	VG	VG	F	VG	VG	G
	X_{12}	MG	VG	VG	VG	VG	VG	G	VG	VG	MG
	X_{13}	G	VG	VG	G	G	G	MG	VG	MG	MG
X_2	X_{21}	G	G	VG	VG	G	G	MG	G	MG	G
	X_{22}	G	VG	VG	VG	G	MG	G	MG	MG	MG
	X_{23}	G	G	VG	G	MG	VG	MP	G	VG	G
	X_{24}	MG	G	VG	G	G	VG	G	G	MG	F

	X_{25}	MG	G	VG	VG	G	F	G	G	F	MG
X_3	X_{31}	G	MG	VG	G	G	VG	G	G	G	F
	X_{32}	G	MG	VG	G	G	VG	G	MP	G	MP
	X_{33}	G	G	VG	G	G	VG	G	F	MG	MP
	X_{34}	MG	G	VG	VG	G	G	G	VG	MG	F
X_4	X_{41}	G	G	VG	G	G	G	G	VG	G	G
	X_{42}	G	G	VG	VG	G	MG	G	VG	VG	G
	X_{43}	G	VG	VG	VG	G	G	G	VG	G	G
	X_{44}	G	VG	VG	VG	G	VG	G	VG	MG	G

Table V below shows that the calculation using the data which is obtained in Table III and linguistic terms from Table I.

TABLE V. FUZZY NUMBER FOR DATA IMPORTANCE WEIGHT

	Respondents				
Criteria	***K1***	***K2***	***K3***	***K4***	***K5***
X1	(0.7,0.9,1)	(0.9,1,1)	(0.7,0.9,1)	(0.9,1,1)	(0.7,0.9,1)
X2	(0.5,0.7,0.9)	(0.9,1,1)	(0.9,1,1)	(0.9,1,1)	(0.7,0.9,1)
X3	(0.5,0.7,0.9)	(0.7,0.9,1)	(0.7,0.9,1)	(0.9,1,1)	(0.7,0.9,1)
X4	(0.7,0.9,1)	(0.9,1,1)	(0.9,1,1)	(0.9,1,1)	(0.7,0.9,1)
	Respondents				
Criteria	***K6***	***K7***	***K8***	***K9***	***K10***
X1	(0.9,1,1)	(0.7,0.9,1)	(0.9,1,1)	(0.9,1,1)	(0.5,0.7,0.9)
X2	(0.9,1,1)	(0.1,0.3,0.5)	(0.7,0.9,1)	(0.5,0.7,0.9)	(0.3,0.5,0.7)
X3	(0.5,0.7,0.9)	(0.7,0.9,1)	(0.1,0.3,0.5)	(0,0.1,0.3)	(0,0,0.1)
X4	(0.9,1,1)	(0.7,0.9,1)	(0.9,1,1)	(0.7,0.9,1)	(0.7,0.9,1)

TABLE VI. FUZZY NUMBER FOR SATISFACTION RATING

Sub-Criteria	**Respondents**				
	K_1	**K_2**	**K_3**	**K_4**	**K_5**
X_{11}	(7,9,10)	(9,10,10)	(9,10,10)	(7,9,10)	(9,10,10)
X_{12}	(5,7,9)	(9,10,10)	(9,10,10)	(9,10,10)	(9,10,10)
X_{13}	(7,9,10)	(9,10,10)	(9,10,10)	(7,9,10)	(7,9,10)
X_{21}	(7,9,10)	(7,9,10)	(9,10,10)	(9,10,10)	(7,9,10)
X_{22}	(7,9,10)	(9,10,10)	(9,10,10)	(9,10,10)	(7,9,10)
X_{23}	(7,9,10)	(7,9,10)	(9,10,10)	(7,9,10)	(5,7,9)
X_{24}	(5,7,9)	(7,9,10)	(9,10,10)	(7,9,10)	(7,9,10)
X_{25}	(5,7,9)	(7,9,10)	(9,10,10)	(9,10,10)	(7,9,10)
X_{31}	(7,9,10)	(5,7,9)	(9,10,10)	(7,9,10)	(7,9,10)
X_{32}	(7,9,10)	(5,7,9)	(9,10,10)	(7,9,10)	(7,9,10)
X_{33}	(7,9,10)	(7,9,10)	(9,10,10)	(7,9,10)	(7,9,10)
X_{34}	(5,7,9)	(7,9,10)	(9,10,10)	(9,10,10)	(7,9,10)
X_{41}	(7,9,10)	(7,9,10)	(9,10,10)	(7,9,10)	(7,9,10)
X_{42}	(7,9,10)	(7,9,10)	(9,10,10)	(9,10,10)	(7,9,10)
X_{43}	(7,9,10)	(9,10,10)	(9,10,10)	(9,10,10)	(7,9,10)
X_{44}	(7,9,10)	(9,10,10)	(9,10,10)	(9,10,10)	(7,9,10)
	K_6	**K_7**	**K_8**	**K_9**	**K_{10}**
X_{11}	(9,10,10)	(3,5,7)	(9,10,10)	(9,10,10)	(7,9,10)
X_{12}	(9,10,10)	(7,9,10)	(9,10,10)	(9,10,10)	(5,7,9)
X_{13}	(7,9,10)	(5,7,9)	(9,10,10)	(5,7,9)	(5,7,9)
X_{21}	(7,9,10)	(5,7,9)	(7,9,10)	(5,7,9)	(7,9,10)
X_{22}	(5,7,9)	(7,9,10)	(5,7,9)	(5,7,9)	(5,7,9)
X_{23}	(9,10,10)	(5,7,9)	(7,9,10)	(9,10,10)	(7,9,10)
X_{24}	(9,10,10)	(7,9,10)	(7,9,10)	(5,7,9)	(3,5,7)
X_{25}	(3,5,7)	(7,9,10)	(7,9,10)	(3,5,7)	(5,7,9)
X_{31}	(9,10,10)	(7,9,10)	(7,9,10)	(7,9,10)	(3,5,7)
X_{32}	(9,10,10)	(7,9,10)	(1,3,5)	(7,9,10)	(1,3,5)
X_{33}	(9,10,10)	(7,9,10)	(3,5,7)	(5,7,9)	(1,3,5)
X_{34}	(7,9,10)	(7,9,10)	(9,10,10)	(5,7,9)	(3,5,7)
X_{41}	(7,9,10)	(7,9,10)	(9,10,10)	(7,9,10)	(7,9,10)
X_{42}	(5,7,9)	(7,9,10)	(9,10,10)	(9,10,10)	(7,9,10)
X_{43}	(7,9,10)	(7,9,10)	(9,10,10)	(7,9,10)	(7,9,10)
X_{44}	(9,10,10)	(7,9,10)	(9,10,10)	(5,7,9)	(7,9,10)

Table VI above shows the fuzzy number for satisfaction rating and Table VII shows the result for fuzzy rating calculation for criterion *i*-th and sub-criterion, *j*-th.

TABLE VII. RESULT FOR FUZZY RATING CALCULATION

Rating	Fuzzy Number	Rating	Fuzzy Number
r_{11}	(6.7,8.5,9.5)	r_{31}	(5.0,6.8,8.3)
r_{12}	(6.2,8.0,9.2)	r_{32}	(4.5,6.2,7.6)
r_{13}	(6.0,7.9,9.2)	r_{33}	(4.7,6.5,8.0)
r_{21}	(5.9,7.8,9.2)	r_{34}	(5.6,7.5,9.0)
r_{22}	(6.0,7.8,9.2)	r_{41}	(6.4,8.2,9.4)
r_{23}	(6.1,8.0,9.2)	r_{42}	(6.3,8.1,9.2)
r_{24}	(5.8,7.8,9.2)	r_{43}	(6.5,8.3,9.4)
r_{25}	(5.6,7.6,9.0)	r_{44}	(6.4,8.2,9.4)

V. RESULTS AND DISCUSSION

In this section, we obtained the fuzzy weight *W*, fuzzy grade matrix G and total fuzzy grade vector R, as follows:

$$W = \begin{bmatrix} w_1 \\ w_2 \\ w_3 \\ w_4 \end{bmatrix} = \begin{bmatrix} (0.64, & 0.81, & 0.92) \\ (0.61, & 0.79, & 0.91) \\ (0.44, & 0.60, & 0.75) \\ (0.66, & 0.84, & 0.95) \end{bmatrix}$$

$$G = \begin{matrix} X_1 \\ X_2 \\ X_3 \\ X_4 \end{matrix} \begin{bmatrix} (6.30, & 8.11, & 9.30) \\ (5.89, & 7.77, & 9.15) \\ (4.95, & 6.74, & 8.22) \\ (6.38, & 8.19, & 9.36) \end{bmatrix}^T$$

Based on [14] ranking method, the value of $\bar{x}$ for each criteria and sub-criteria shown in Table 5.

TABLE VIII. CENTROID POINT FOR CRITERIA AND SUB-CRITERIA

Criteria	Centroid value	Ranking	Sub-criteria	Centroid value	Ranking
X_1	6.39	3	r_{11}	8.23	1
			r_{12}	7.78	2
			r_{13}	7.70	3
X_2	6.02	4	r_{21}	7.64	3
			r_{22}	7.65	2
			r_{23}	7.75	1
			r_{24}	7.59	4
			r_{25}	7.40	5
X_3	6.64	2	r_{31}	6.83	2
			r_{32}	6.10	4
			r_{33}	6.43	3
			r_{34}	7.36	1
X_4	6.70	1	r_{41}	8.00	2
			r_{42}	7.86	4
			r_{43}	8.07	1
			r_{44}	7.98	3

The best ranking is achieved from calculation of importance weight and satisfaction rating. For the main criteria, the best ranking is X_4 (Staff Service) followed by internet access, environment at the library and information about library. The ranking result for the main criteria is $X_4 \succ X_3 \succ X_1 \succ X_2$. While for the sub-criteria, the best ranking was obtained as follows:

$$X_1 : r_{11} \succ r_{12} \succ r_{13}$$
$$X_2 : r_{23} \succ r_{22} \succ r_{21} \succ r_{24} \succ r_{25}$$
$$X_3 : r_{34} \succ r_{31} \succ r_{33} \succ r_{32}$$
$$X_4 : r_{43} \succ r_{41} \succ r_{44} \succ r_{42}$$

For criteria 1, the best sub-criteria was that the place for studying is comfortable, followed by possibilities for using computers and the design of the library homepage.

While for criteria 2, the best sub-criteria was that reliability references of services followed by informativeness of the library website, the correctness of e-catalogue, advising about library services and facilities and the last sub-criterion is the representation of relevant e-journals and database.

User friendliness of e-catalogue was the best for criteria 3. The suitability of open hours for internet access was chosen as the second and followed by the correctness of fulfilling requires for internet access and serving speed for internet access.

Staff willingness to help customers has become the best sub-criteria for criteria 4. Next is staff competence, staff ability to answer customer's questions followed by staff friendliness.

Based on this research, a library should widely promote their informative systems that they already established. This will make it easier for the students to find needed materials and to accomplish their assignments and research work.

Library management should improve the environment at the library so that students will be able to study comfortably with complete facilities provided by the library. Hopefully, it will encourage students to revisit the library and used all the facilities needed for their learning process.

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