Identifying Relative Weights of Evaluation Indices for Library Website Usability Acceptance Model by Applying the Extent Analysis Fuzzy AHP Approach

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ABSTRACT: *A library website plays an enhanced role compared to its traditional physical library while providing a wide variety of library services to its users. Evaluation of library websites is a key to realize the extent of user acceptance to the website and to improve overall quality of website. Usability is a highly recognized factor to determine how easy to use the website. The models of usability evaluations evaluate the ease of use of website operations and see whether the users can perform their tasks easily. Moving on further, this study has been undertaken in context of library websites in Sri Lanka with the main purpose of exploring the favourable weights of the seven key dimensions and 20 measuring items with the aids of experts in the related field. These dimensions and measuring items were identified from our previous study which have been tested its reliability and validity in assessing library website usability in Sri Lanka with the aids of actual library users in Sri Lanka. Fuzzy theories together with the extent analysis fuzzy analytic hierarchy process method were applied. It was expected to identify the relative importance of the criteria of interest while avoiding uncertainty, ambiguity, loss of data, and difficulties faced in assessment cycle. Triangular fuzzy numbers were used to represent the judgments on the relative importance between each pair of factors that makes experts consensus uniform rather than using linguistic values. The research findings concluded that satisfaction was the dimension that the experts considered most important in evaluating library website usability. The experts rated accessibility as the least important dimension.*

Keywords: Library Website Evaluation, Fuzzy AHP, Usability Evaluation, Website Usability

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1. Introduction

With the rapid development of internet technology and information technology, website of an organization has taken an important place as a virtual image and a public interface for information seekers around the world. Website is regarded as a global gateway to enter the knowledge repositories and achieve required services. Thus the websites have been identified as an easiest and effective way of distributing information and procuring services to its clients. In addition, greater research impact, attracting visitors and serving services on time are the benefits which can be gained from of an effective website [1]. Therefore, according to the fast changing environment of the technology, organizations need to develop instructive and rich websites with continuous monitoring and updating mechanisms[2].

Today, website is considered as a lifeline of libraries worldwide. Websites are mainly used as a virtual image and promotional platform of the library that displays information and services of a library. Presently, libraries draw attention to promote e-resources, online catalogues, web 2.0 services, and online reference services through their websites. By providing the said services they expect to achieve the existing challenges of promoting better visibility for their print resources, offering various value added electronic services, and providing an access to quality content in electronic form. In addition, user satisfaction to the website is another big demand for the libraries. User satisfaction can be achieved if the interface and content of the library website have fulfilled with the usability principles [3]. Therefore, developing usable websites so as to meet the demands of information and services is essential for library's success since users touch, feel, search, and experience information and services that provide mainly through websites [4]. Usability is considered as the most important item of the website while it measures the simplicity of the website [5]. In the recent years, usability evaluations, especially, in commercial websites have been conducted to diagnose problems of current websites and to enhance website interfaces by better reflecting user viewpoints. As a result of usability evaluation, a positive attitude to the website and revisit rates can be increased effectively. On the other hand, it supports to reduce website development, maintenance, and support costs as well [6]. Because of each website has different kind of features and different categories of user requirements, the usability measuring criteria used for evaluating the websites may be different [7]. However, there is a lack of consensus on the construct of website usability and how to measure them. Thus different set of website usability dimensions with different important levels were taken to measure the usability in specific type of websites in previous studies [4]. Nevertheless, there are no sufficient researches conducted in library websites usability evaluations. In the literature review, it has been found that no any specific research studies conducted related to university or other type of library website usability evaluation in Sri Lanka country context.

In this backdrop, we have identified a major measurement instrument dimensions and their measurement items for usability evaluation specific to a library websites in Sri Lanka which were validated its reliability and validity from our previous study. The final usability evaluation model consisted of the seven dimensions and two to three measurement items for each dimension as shown in Table 1. Subsequently, it is essential to ascertain and prioritize relative weights of the key dimensions and measuring items to ensure successful implementation of library website usability index system. Therefore, the main purpose of this paper is to assess the key dimensions and measuring items weights of a library website usability evaluation index system through the extent analysis fuzzy analytic hierarchy process method.

The remainder of this paper is organized as follows. Section 2 reviews the prior research related to the topic.

Section 3 describes preliminaries including fuzzy theory with fundamental fuzzy number operations related to concepts. The methodology that referred to determine relative weights of the key dimensions and measuring items for library website usability index system describes in section 4. Section 5 deals with factors determining the key dimensions and measuring items weights for library website usability acceptance model. Section 6 provides an account of findings and means of applications. The paper is concluded with avenues for future research in section 7.

2. Related Previous Works

It can be seen that the Multiple Criteria Decision Making (MCDM) techniques were applied by many researchers to find out the weights of criteria in different disciplines. The linear weighting methods (LW), Mathematical Programming (MP) techniques, the Analytic Network Process (ANP), the Analytic Hierarchy Process (AHP), and Fuzzy AHP (FAHP) are the leading MCDM problem solving techniques used in prior researches. Herein, LW that accommodates equal weights for each measuring attributes considered as a simple MCDM method. On the other hand, significant problems arise when handling qualitative criteria in MP techniques while AHP is considered as an ineffective tool because of the inherent imprecision and uncertainty connected with the mapping of a decision maker's assessment to exact numbers. ANP can be used to solve MCDM problems wherein the criteria affect each other and have nonlinear correlation. The fuzzy based AHP approach is a more effective solution to solve MCDM related problems because it's powerful ability to deal with imprecise and uncertain data. Further, it support to decision makers to assign linguistic variables in the form of numeric values to express their judgments and there has a possibility to incorporate the incomplete, unobtainable and unquantifiable information into the decision model in fuzzy environment [8-11].

Thus, it can be seen that FAHP methods has been widely applied to solve different MCDM related problems. For example, studies by Chen, Hsieh and Do [11] have determined the factors and sub-factors weights of teaching performance evaluation system applying the extent analysis FAHP method; Mikhailov and Tsvetinov [12] have proposed FAHP based ranking service offers model by addressing the problem of uncertainty and imprecision; Gungor *et al.* [13] have designed a MCDM model to select the most adequate person for the job adopting FAHP approach and Yager's weighted method to determine the criteria weights; Chou *et al.* [14] have developed a framework for evaluate the performance of science and technology human resources using Evaluation Laboratory (DEMATEL) and fuzzy Decision-making Trial methods. This framework has employed FAHP to obtain the criteria weights; Taylana *et al.* [15] have applied FAHP to find the favorable weights of the key risk criteria for the construction projects evaluation; Sadeghi, Moghimi and Ramezan [16] have applied FAHP to find the weights of each factor affected on knowledge management execution readiness; Mehralian *et al.* [17] have ranked and prioritized critical success factors that affect total quality management in the pharmaceutical industry adopting fuzzy TOPSIS technique; Moghimi and Jusan [18] have applied non-structural FAHP method to determine housing preference decision criteria weights; Liu *et al.* [19] have conducted a study to determine weights of evaluation factors for e-commerce websites ranking using FAHP techniques; Nagpal *et al.* [7] used the extent analysis fuzzy AHP method to obtain the criteria and sub-criteria weights while developing a website ranking system based on Fuzzy TOPSIS method; By using the extent analysis fuzzy AHP method, Atalay and Eraslan [20] have examined the criteria weights for usability evaluation of MP3 players.

Furthermore, some studies have been used other MCDM methods to examine the criteria importance in real-life decision-making problem solving. For example, studies by Pearson, Pearson and Green [21] have applied linear regressions, MCDM approach and Tukey's honestly significant differences methods to investigate the relative importance of five website usability criteria; A study done by Calisir *et al.* [22] have analysed the relative importance of the online auction and shopping website usability criteria using the ANP method; Kamal and Alsudairi [23] have investigated the integration technologies factor importance in local government authorities through AHP technique; By using AHP, Roy, Pattnaik and Mall [24] have examined the factor weights for evaluation of quality assurance of academic websites. In summary, FAHP methods are suited to determine the criteria weights of the evaluation systems efficiently and effectively due to its highly applicability for solve MCDM problems.

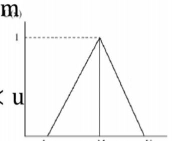
3. Preliminaries

3.1. Fuzzy Sets and Fuzzy Numbers

Fuzzy set theory was developed by Professor Zadeh in 1965, that transforms conceptual language into a mathematic form to explain human behavioural fuzziness by a set of values with more flexible and better expresses human thinking when it is applied to decision making problems [25-26]. Van Laarhoven and Pedrycz [27] initially introduced the FAHP with employing the Trangular Fuzzy Number (TFN) to represent a pair-wise comparison ratio in AHP. Buckley [28] has initially applied fuzzy set theory for improvements of the traditional AHP with introducing fuzzy ratios into the pair-wise comparisons. The FAHP replaces the exact values of the AHP with interval values, which enables to evaluate problems in a more human scale and provides correlative values for evaluation factors [26]. Because the FAHP have saturated with a systematic methods to handle incomplete information also, decision makers can use FAHP for comparison and weighting of the criteria and alternatives easily with incomplete information. According to Dominic and Khan [29], the fuzzy algorithms that use fuzzy logic and fuzzy sets, which are the most useful mathematical tools for modelling, is one of the main approaches to evaluate the MCDM problems.

A fuzzy number can be described by a given interval between 0 and 1 of real numbers [30] and a triangular fuzzy number is a distinctive category of fuzzy number including three real numbers (l, m, u) [31]. Let x be a fuzzy number, then the membership function can be illustrated as:

$$\mu_A(x) = \begin{cases} (x-l)/(m-l) & l \ll x \ll m \\ (u-x)/(u-m) & m \ll x \ll u \\ 0 & \text{otherwise} \end{cases} \quad (1)$$



where m is the most potential value of fuzzy number A, and l and u are the lower and upper bounds of the fuzziness of the data evaluated, respectively.

Level 1: Goal	Level 2: Dimensions	Level 3: measuring items
Calculating the weights of all key dimensions and measuring items for library website usability index system	Accessibility (D_1)	Pages loading speed on this site is acceptable (D_{11})
		Visual appeal of the site is satisfying(D_{12})
		Site is in online every time (D_{13})
	Content (D_2)	There is an archive of previously published materials or articles (D_{21})
		The textual content and illustrations are up-to-date(D_{22}) Ads & pop-ups are not apparent(D_{23})
	Efficiency (D_3)	The website is well organized to find what I want (D_{31})
		I can quickly complete a resource-finding task without any difficulties (D_{32})
	Learnability (D_4)	The terminologies used on this library website were easily understandable (D_{41})
		It was easy to learn to use this library (D_{42})
		This library website provides appropriate help functions and information (D_{43})
	Navigation (D_5)	The current location is clearly indicated in each web pages (D_{51})
		The Home page has included links to access all major parts of the site (D_{52})
		Structure of the website looks simple without any unnecessary levels (D_{53})
	Satisfaction (D_6)	I like to recommend this site to my colleagues for getting information (D_{61})
		I am satisfied with this library overall (D_{62})
		It is a pleasure to use this library website to find what I want (D_{63})
	Usefulness (D_7)	Accuracy of information on this site is satisfying (D_{71}) Quality of information on this site is acceptable (D_{72}) E-reference sources provided through the site are satisfying (D_{73})

Table 1. The hierarchical structure of key dimensions and measuring items for library website usability index system

3.2 Algebraic Operations in Fuzzy Theory

Let two positive triangular fuzzy numbers namely, $A = (l_1, m_1, u_1)$ and $B = (l_2, m_2, u_2)$. The basic fuzzy arithmetic operations on these fuzzy numbers can be defined as [30]:

a) Inverse $A^{-1} = \left(\frac{1}{u_1}, \frac{1}{m_1}, \frac{1}{l_1}\right)$

b) Addition $A + B = (l_1 + l_2, m_1 + m_2, u_1 + u_2)$

c) Subtraction $A - B = (l_1 - u_2, m_1 - m_2, u_1 - u_2)$

d) Scalar Multiplication $\begin{matrix} \forall k > 0, k \in R, kA = (kl_1, km_1, ku_1) \\ \forall k < 0, k \in R, kA = (ku_1, km_1, kl_1) \end{matrix}$

e) Multiplication $AB = (l_1 l_2, m_1 m_{2,} u_1 u_2)$

f) Division $\frac{A}{B} = \left(\frac{l_1}{u_2}, \frac{m_1}{m_2}, \frac{u_1}{l_2}\right)$

3.3. Linguistic Variables and Fuzzy Conversion Scale

A linguistic variable is a variable whose values represent from words or sentences in a natural or artificial language while it can be easily applied in such situation that are complicated and hard to define [32]. The corresponding linguistic scales for rating the pair-wise comparisons of dimensions importance level on a qualitative scale are defined as, “just equal”, “equally important”, “moderately more important”, “strongly more important”, “very strongly more important” and “extremely more important”. Then the linguistic scales are converted into fuzzy numbers using the triangular fuzzy conversion scale ranging from 1 to 7 according to the Figure 1 and Table 2 [33].

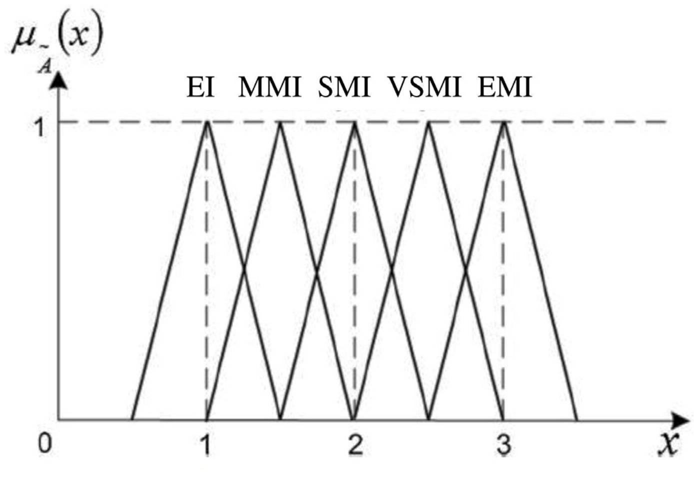


Figure 1. Linguistic scale for relative importance

4. Methodology

The main objective of this study is to determine relative weightings of the key dimensions and measuring items to ensure successful implementation of library website usability index system. For that, Chang’s extent analysis fuzzy AHP method [34] was employed because of its highly applicability such type of evaluations.

4.1. Developing the Hierarchical Structure

The hierarchical structure of the problem can be drawn by combining all the key dimensions and measuring items that affect to the library website usability specific to the research problem.

4.2. Establishing a Group of Experts in the Field

A committee of experts in the related field was formed to determine the relative importance of key dimensions and measuring items. The experts have expressed relative importance between each pair of factors verbally as just equal, equally important, moderately more important, strongly more important, very strongly more important and extremely more important which are in the form of linguistic variables with the help of questionnaires.

Linguistic scale for importance	Triangular fuzzy scale	Triangular fuzzy reciprocal scale
Just Equal (JE)	(1, 1, 1)	(1, 1, 1)
Equally Important (EI)	(1/2, 1, 3/2)	(2/3, 1, 2)
Moderately More Important (MMI)	(1, 3/2, 2)	(1/2, 2/3, 1)
Strongly More Important (SMI)	(3/2, 2, 5/2)	(2/5, 1/2, 2/3)
Very Strongly More Important (VSMI)	(2, 5/2, 3)	(1/3, 2/5, 1/2)
Extremely More Important (EMI)	(5/2, 3, 7/2)	(2/7, 1/3, 2/5)

Table 2. Linguistic scales and fuzzy scales for importance

4.3. Establishing Comparison Matrices

The descriptive judgments which are in the form of linguistic variables are then translated into the triangular fuzzy scale as defined in Table II to construct the comparison matrix of each level with *n* factors, $\tilde{A} = \{\tilde{a}_{ij}\}$ that represents the relative importance of factor *i* to *j*. For example, if the decision maker expressed that the factor *i* is very strongly more important when compared with factor *j*, then $\widetilde{a_{ij}}$ = (2,5/2,3), otherwise $\widetilde{a_{ij}}$ = (1/3,2/5,1/2). Herein, $n(n-1)/2$ pair-wise comparison judgments required at a level with n elements for construct the comparison matrix and the comparison matrices need to be constructed for main level factors and sub-level factors in each main level factors.

$$\tilde{A} = \begin{bmatrix} 1 & \tilde{a}_{12} & \cdots & \tilde{a}_{1n} \\ \tilde{a}_{21} & 1 & \ldots & \tilde{a}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{a}_{n1} & \tilde{a}_{n2} & \cdots & 1 \end{bmatrix} = \begin{bmatrix} 1 & \tilde{a}_{12} & \cdots & \tilde{a}_{1n} \\ 1/\tilde{a}_{12} & 1 & \ldots & \tilde{a}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ 1/\tilde{a}_{1n} & 1/\tilde{a}_{2n} & \cdots & 1 \end{bmatrix} \tag{2}$$

4.4. Calculating the Consistency Index and Consistency Ratio of Comparison Matrix

The consistency of an evaluation needs to be analysis to confirm whether the expert decisions were in a certain quality level before processing ahead. Saaty [35] has proposed a index method to measure the crisp pair-wise comparison matrices consistency level. So, the fuzzy comparison matrices need to be transformed into crisp matrices using any defuzzification method [11].

4.5. Construct Crisp Performance Matrix

The defuzzification methods have a capability to convert the triangular fuzzy number into a crisp number effectively. So in this study, the authors decided to use the defuzzification method proposed by Chang, Wu and Lin [8] that use the decision maker's degree of confidence (α) regarding criteria weights and risk tolerance (λ) of decision-makers for convert fuzzy comparison matrix into crisp matrix.

Herein, the value of α may be in between 0 and 1, and it will help to evade the complicated and unreliable practices [36]. A larger a value represents decision maker's assessments are more confident and closer to the most possible value, i.e. *m*, of the triangular fuzzy numbers (*l, m, u*). In practical applications, $\alpha = 1$; $\alpha = 0.5$, and $\alpha = 0$ are used to indicate that the decision maker involvement is in an optimistic, moderate, or pessimistic view, respectively [30, 37]. Additionally, λ can be considered as the degree of a decision maker's optimism and its range is also between 0 and 1. The attitude of the decision maker can be positive, moderate or negative and accordingly they will have higher, average and less values for their fuzzy assessments. In practical applications, $\lambda = 1$, $\lambda = 0.5$ and $\lambda = 0$ are used to indicate optimistic, moderate, or pessimistic view respectively [7].

In order to aforesaid information, a triangular fuzzy number ($\widetilde{a_{ij}} = (l_{ij}, m_{ij}, u_{ij})$) can be defuzzified to a crisp number as follows.

$$\left(a_{ij}^{\alpha}\right)^{\lambda} = \left[\lambda * l_{ij}^{\alpha} + (1-\lambda) * u_{ij}^{\alpha}\right], 0 \le \lambda \le 1, 0 \le \alpha \le 1 \qquad (3)$$

Here, $l_{ij}^{\alpha} = \left(m_{ij} - l_{ij}\right) * \alpha + l_{ij}$ represents the left end value of α-cut for a_{ij}, and $u_{ij}^{\alpha} = u_{ij} - \left(u_{ij} - m_{ij}\right) * \alpha$ represents the right end value of α-cut for a_{ij}.

Then the crisp performance matrix can be expressed from the crisp numbers as follows:

$$\left[(A^{\alpha})^{\lambda}\right] = \left[\left(a_{ij}\right)^{\lambda}\right] = \begin{bmatrix} 1 & (a_{12}^{\alpha})^{\lambda} & \cdots & (a_{1n}^{\alpha})^{\lambda} \\ (a_{21}^{\alpha})^{\lambda} & 1 & \cdots & (a_{2n}^{\alpha})^{\lambda} \\ \vdots & \vdots & \ddots & \vdots \\ (a_{n1}^{\alpha})^{\lambda} & (a_{n2}^{\alpha})^{\lambda} & \cdots & 1 \end{bmatrix} \qquad (4)$$

4.6. Calculate Largest Eigen Value of the Crisp Performance Matrix (λ_{max})

The largest eigen value of the crisp performance matrix was calculated using the following scheme:

• Calculate the sum of each column of the crisp performance matrix

• Divide each element of the crisp performance matrix with the sum of its column

• Take averaging values across the rows

• Calculate the sum of product of the sum of each column and averaging values across the rows

4.7. Calculate the Consistence Index (CI)

The Consistence Index (CI) for each comparison matrix can be calculated as follows:

$$CI = \frac{\lambda_{max} - n}{n-1} \qquad (5)$$

where λ_{max} is the largest eigen value of the crisp performance matrix and *n* is the dimension of the matrix.

4.8. Calculate the Consistency Ratio (CR)

The Consistency Ratio (CR) can be computed by dividing the consistency index from the consistency of a random matrix [35] asfollows.

$$CR = \frac{CI}{RI(n)} \qquad (6)$$

where *RI*(*n*) is a random consistency index and its value is depended on the size on matrix as follows [35]: If *n* = 1, 2, 3, 4, 5, 6, 7, 8, 9, or 10 then *RI* = 0, 0, 0.58, 0.9, 1.12, 1.024, 1.32, 1.41, 1.45, or 1.49 respectively.

The acceptable CR value should be equal or less than 0.1. Otherwise, the related pair-wise comparisons should be repeated till CR comes in the required level [35].

4.9. Constructing the Representative Comparison Matrix of all Decision-Makers

After constructing the comparison matrices according to each expert's opinion, aggregation is necessary to represent one comparison matrix for each level and sub-level factors. For that, the conventional AHP concepts can be employed in the FAHP environment while the AHP used geometric mean functions that satisfy the pareto principle and homogeneity condition for aggregating group decisions. If a group of *K* decision makers make pair-wise comparisons of the importance of *n* factors, then we get a set of *K* comparison matrices, $\widetilde{A}_k = \{\tilde{a}_{ijk}\}$,where $\tilde{a}_{ijk} = (l_{ijk}, m_{ijk}, u_{ijk})$. Therefore, the triangular fuzzy numbers in the group comparison matrix can be obtained by using the Eq. (7) – Eq. (9) [11].

$$l_{ij} = \min_{k=1,2,.....K}(l_{ijk}) \tag{7}$$

$$m_{ij} = \sqrt[K]{\prod_{k=1}^{K} m_{ijk}} \tag{8}$$

$$u_{ij} = \max_{k=1,2,.....K}(u_{ijk}) \tag{9}$$

4.10. Calculating the Factor and Sub-Factor Weights

Chang's [34] extent analysis FAHP method can be used to determine factor weights of the MCDM problems with minimum efforts. When comparing with other methods, this method needs lower computation complexity with more efficiency [34].

The steps of the Chang's method can be described as follows:

Let a fuzzy pair-wise comparison matrix be $\widetilde{A} = (\tilde{a}_{ij})$ and $\tilde{a}_{ij} = (l_{ij}, m_{ij}, u_{ij})$

Step 1. The fuzzy synthetic extent value according to the i^{th} object is defined as

$$S_i = \sum_{j=1}^{m} M_{ij} * \left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{ij}\right]^{-1} \tag{10}$$

$$\sum_{j=1}^{m} M_{ij} = \left(\sum_{j=1}^{m} l_{ij}, \sum_{j=1}^{m} m_{ij}, \sum_{j=1}^{m} u_{ij}\right), i = 1, 2, \ldots\ldots, n \tag{11}$$

$$\sum_{i=1}^{n}\sum_{j=1}^{m} M_{ij} = \left(\sum_{i=1}^{n}\sum_{j=1}^{m} l_{ij}, \sum_{i=1}^{n}\sum_{j=1}^{m} m_{ij}, \sum_{i=1}^{n}\sum_{j=1}^{m} u_{ij}\right) \tag{12}$$

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{ij}\right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n}\sum_{j=1}^{m} u_{ij}}, \frac{1}{\sum_{i=1}^{n}\sum_{j=1}^{m} m_{ij}}, \frac{1}{\sum_{i=1}^{n}\sum_{j=1}^{m} l_{ij}}\right) \tag{13}$$

Step 2. The degree of possibility of $S_j = (l_j, m_j, u_j) \geq S_i = (l_i, m_i, u_i)$ is defined by comparing the values of S_i as follows:

$$V(S_j \geq S_i) = \text{height}(S_i \cap S_j) = \begin{cases} 1 & \text{if } m_j \geq m_i \\ 0 & \text{if } l_i \geq u_j \\ \frac{l_i - u_j}{(m_j - u_j) - (m_i - l_i)} & \text{otherwise} \end{cases} \tag{14}$$

Figure 2 represents $V(S_j \geq S_i)$, for the case $m_j < l_i < u_j < m_i$, where *d* represents the abscissa value of the highest intersection point between S_j and S_i. Herein, the both values $V(S_j \geq S_i)$ and $V(S_i \geq S_j)$ are needed to compare S_i and S_j.

Step 3. The minimum degree of possibility $d(i)$ of $V(S_j \geq S_i)$ for $i, j = 1, 2, 3 \ldots, k$ can be defined as follows.

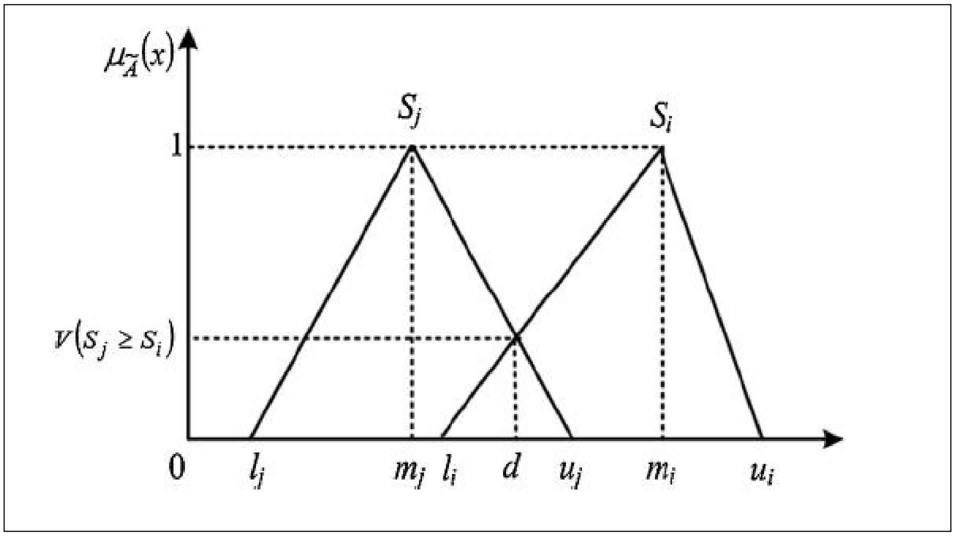


Figure 2. Intersection between S_j and S_i

$$V\,[(S \geq S_1) \text{ and } (S \geq S_2) \text{ and} \ldots (S \geq S_k) = min V\,(S \geq S_i)\,, i = 1, 2, 3, \ldots\ldots, k \quad (15)$$

Assume that $d(A_i) = min\ V(S \geq S_i)$, for i = 1, 2, 3, . . ., k. Then the weight vector is defined as:

$$W/ = (d/\,A_1\,, d/\,A_2\,, \ldots\ldots\ldots, d/\,A_n))\,^T \quad (16)$$

where A_i = 1, 2, 3,…., n comprises n elements

Step 4. Finally, the weight vectors can be normalized as follows:

$$W = (W_1, W_2, \ldots, W_n)T \quad (17)$$

where $W_1, W_2, \ldots, W_n$ are non- fuzzy numbers .

5. Establishing the Key Dimensions and Measuring Items Weights of a Library Website Usability Evaluation Index System

In this section, the weights of key dimensions and measuring items for library website usability evaluation model are provided. The hierarchical structure of decision-making process was presented in Table 1. To acquire the key dimensions and measuring items weights, a pair-wise questionnaire was distributed to a group of 20 experts, including two professors of computer science, five senior lecturers of computer science, five senior assistant librarians, five web designers and three postgraduate students to get their viewpoints. The research period was January 2017 to February 2017.

The comparison matrices for each expert's assessment at the corresponding level with respect to the upper level were constructed based on their assessments on the relative importance between each pair of factors and then the representative comparison matrices for each factor were constructed by applying the geometric mean method as in Eq. (19). The resultant comparison matrices were shown in Tables 3-10.

The next step is to calculate the consistency ratio of the comparison matrices. The crisp comparison matrices allowing the decision maker's degree of confidence (α) as 0.5, denotes that environmental uncertainty is steady and optimism index value (λ) as 0.5 that expresses the attitude is fair for all the key dimensions and all measuring items were obtained using Eq. (3) and Eq. (4). Then, by employing Eq. (5) and Eq. (6), the CR value of the key dimensions comparison matrix is 0.0515 and the CR values of the comparison matrices of the measuring items within each dimension (Accessibility, Content, Efficiency, Learnability, Navigation,

	D1	D2	D3	D4	D5	D6	D7
D1	(1,1,1)	(0.5,1.0292,3.5)	(0.3333, 0.6228,2)	(0.3333,0.8503, 1.2821)	(0.2857,0.467, 0.6163)	(0.2857,0.3586, 0.4373)	(0.2857,0.4141, 0.5247)
D2	(0.2857,0.9 716,2)	(1,1,1)	(0.3333, 0.7402,3)	(0.4,1.064 9,3.5)	(0.2857,0.4787, 0.6376)	(0.2857,0.3651, 0.4472)	(0.2857,0.4234, 0.54)
D3	(0.5,1.6057 ,3)	(0.3333,1.3 51,3)	(1,1,1)	(0.4,1.3 741,3.5)	(0.2857,0.5757, 0.7325)	(0.2857,0.3586, 0.4373)	(0.2857,0.4756, 0.5988)
D4	(0.3333,1.1 761,3)	(0.2857,0.93 91,2.5)	(0.2857,0.7277, 2.5)	(1,1,1)	(0.2857,0.4621, 0.6051)	(0.2857,0.3734, 0.4603)	(0.2857,0.4141, 0.5247)
D5	(1,2.1411,3 .5)	(1,2.0889, 3.5)	(0.3333,1.73 7,3.5)	(1,2.1638,3.5)	(1,1,1)	(0.2857,0.5564, 0.6796)	(0.2857,0.6683, 0.8185)
D6	(2,2.789,3. 5)	(2,2.7386, 3.5)	(2,2.78 9,3.5)	(1.5,2.6782,3.5)	(0.2857,1.7972, 2.1473)	(1,1,1)	(0.3333,1.2011, 1.4651)
D7	(1.5,2.4151 ,3.5)	(1.5,2.3618,3.5)	(0.4,2.10 24,3.5)	(1.5,2.4151,3.5)	(0.3333,1.4963, 1.8074)	(0.3333,0.8326, 1.0238)	(1,1,1)

Table 3. Comparison Matrix of The Key Dimensions

	D11	D12	D13
D11	(1, 1, 1)	(0.3333, 1 .5582, 3.5)	(1.5, 2.2772, 3.5)
D12	(0.2857, 0.6418, 3)	(1, 1, 1)	(0.3333, 1.4823, 2.5)
D13	(0.2857, 0.4391, 0.6667)	(0.4, 0.6746, 3)	(1, 1, 1)

Table 4. Comparison matrix of the measuring items within “Accessibility (D1)”

	D21	**D22**	**D23**
D21	(1,1,1)	(0.2857, 0.4124, 0.6667)	(0.4, 1.8837, 3.5)
D22	(1.5, 2.425, 3.5)	(1,1,1)	(1.5, 2.4696, 3.5)
D23	(0.2857, 0.5309, 2.5)	(0.2857,0.4049,0.6667)	(1,1,1)

Table 5. Comparison matrix of the measuring items within “Content (D2)”

	D31	D32
D31	(1, 1, 1)	(0.2857, 0.617, 2.5)
D32	(0.4, 1.6207, 3.5)	(1,1,1)

Table 6. Comparison matrix of the measuring items within “Efficiency (D3)”

	D41	D42	D43
D41	(1,1,1)	(0.2857,0.749,3)	(1,2.2533,3.5)
D42	(0.3333,1.3351,3.5)	(1,1,1)	(1.5, 2.3714, 3.5)
D43	(0.2857,0.4438,1)	(0.2857,0.4217,0.6667)	(1,1,1)

Table7. Comparison matrix of the measuring items within "Learnability (D4)"

	D51	D52	D53
D51	(1,1,1)	(0.2857,0.4092, 1)	(0.3333,0.949,3)
D52	(1,2.4437,3.5)	(1,1,1)	(0.5,1.8421,3)
D53	(0.3333,1.0537,3)	(0.3333,0.5428,2)	(1,1,1)

Table 8. Comparison matrix of the measuring items within "Navigation (D5)"

	D61	D62	D63
D61	(1,1,1)	(0.2857,0.4467,1)	(0.2857,0.4289,1)
D62	(1,2.2388,3.5)	(1,1,1)	(0.4,1.1962,3.5)
D63	(1,2.3315,3.5)	(0.2857,0.836,2.5)	(1,1,1)

Table 9. Comparison matrix of the measuring items within "Satisfaction (D6)"

	D71	D72	D73
D71	(1, 1, 1)	(0.5, 2.0694, 3.5)	(0.5, 1.9616, 3.5)
D72	(0.2857, 0.4832, 2)	(1,1,1)	(0.3333, 0.7597, 2.5)
D73	(0.2857, 0.5098, 2)	(0.4, 1.3164, 3)	(1, 1, 1)

Table 10. Comparison matrix of the measuring items within "Usefulness (D7)"

Satisfaction and Usefulness) are 0.0110, 0.0277, 0.0587, 0.0321, 0.0180, 0.0316 and 0.0490. The results of the comparison matrices and the representative matrices consistency test were in less than 0.1. Thus, the consistency in each matrix is acceptable level.

After this point, the study has turned to get the key dimensions and measuring items weights by taking pair-wise comparison matrices of the key dimensions and measuring items in each dimension by applying the extent analysis fuzzy AHP method.

The fuzzy synthetic extent values of key dimensions comparison matrix were obtained using Eq. (10) – Eq. (13) and the results are as follows:

S1 = (0.0314,0.0796,0.2894),

S2 = (0.0299,0.0846,0.3440),

S3 = (0.0321,0.1131,0.3793),

S4 = (0.0287,0.0855,0.3274),

S5 = (0.0509,0.1738,0.5101),

S6 = (0.0947,0.2516,0.5755),

S7 = (0.0682,0.2118,0.5513)

Then the degree of possibility of $S_j = (l_j, m_j, u_j) \geq S_i = (l_i, m_i, u_i)$ was taken from individually comparing the values of S_i as in Eq. (14) and the values of $V(S_i \geq S_j)$ shows in Table 9.

$V(S_1>S_j)$	Value	$V(S_2>S_j)$	Value	$V(S_3>S_j)$	Value	$V(S_4>S_j)$	Value	$V(S_5>S_j)$	Value	$V(S_6>S_j)$	Value	$V(S_7>S_j)$	Value
$V(S_1>S_2)$	0.9808	$V(S_2>S_1)$	1.0000	$V(S_3>S_1)$	1.0000	$V(S_4>S_1)$	1.0000	$V(S_5>S_1)$	1.0000	$V(S_6>S_1)$	1	V(S7>S1)	1.0000
$V(S_1>S_3)$	0.8847	$V(S_2>S_3)$	0.9163	$V(S_3>S_2)$	1.0000	$V(S_4>S_2)$	1.0000	$V(S_5>S_2)$	1.0000	$V(S_6>S_2)$	1	V(S7>S2)	1.0000
$V(S_1>S_4)$	0.9779	$V(S_2>S_4)$	0.9974	$V(S_3>S_4)$	1.0000	$V(S_4>S_3)$	0.9144	$V(S_5>S_3)$	1.0000	$V(S_6>S_3)$	1	V(S7>S3)	1.0000
$V(S_1>S_5)$	0.7168	$V(S_2>S_5)$	0.7668	$V(S_3>S_5)$	0.8441	$V(S_4>S_5)$	0.7579	$V(S_5>S_4)$	1.0000	$V(S_6>S_4)$	1	V(S7>S4)	1.0000
$V(S_1>S_6)$	0.5309	$V(S_2>S_6)$	0.5989	$V(S_3>S_6)$	0.6727	$V(S_4>S_6)$	0.5835	$V(S_5>S_6)$	0.8422	$V(S_6>S_5)$	1	V(S7>S5)	1.0000
$V(S_1>S_7)$	0.6258	$V(S_2>S_7)$	0.6844	$V(S_3>S_7)$	0.7591	$V(S_4>S_7)$	0.6723	$V(S_5>S_7)$	0.9207	$V(S_6>S_7)$	1	V(S7>S6)	0.9199

Table 11. Values of $V(S_i \geq S_j)$

The minimum degree of possibility $d/\ i$ of $V(S_i \geq S_j)$ for $i, j = 1, 2, \ldots, 7$ was found by using Eq. (15) and the weight vector ($W/$) was calculated from Eq. (16).

$$W/ = (0.5309, 0.5989, 0.6727, 0.5835, 0.8422, 1, 0.9199)$$

Finally, the relative weights of the seven dimensions were obtained from normalizing the weight vector using Eq. (17).

$$W = (W_{D1}, W_{D2}, W_{D3}, W_{D4}, W_{D5}, W_{D6}, W_{D7}) = (0.1031, 0.1163, 0.1307, 0.1133, 0.1636, 0.1942, 0.1787)$$

The dimension "Satisfaction (D6)" plays the most important part (19.42%) in library website usability, followed by "Usefulness (D7)".

The relative weight vectors of the measuring items within each dimension were determined following the above similar calculation and Table 12 summarizes the normalized weight vectors of the key dimensions and measuring items for library website usability evaluation index system.

Table 12 Weight vectors of the key dimensions and measuring items

6. Discussion

Active presence of libraries on the internet has helped libraries to move one step ahead in the Internet era in order to serve their

Dimension	Weights of Dimension	Measuring Item	Weights of Measuring Item
Accessibility (D_1)	0.1031	D11 D12 D13	0.3942 0.3322 0.2735
Content (D_2)	0.1163	D21 D22 D23	0.3110 0.4620 0.2269
Efficiency (D_3)	0.1307	D31 D32	0.4525 0.5475
Learnability (D_4)	0.1133	D41 D42 D43	0.3881 0.4150 0.1969
Navigation (D_5)	0.1636	D51 D52 D53	0.2281 0.4012 0.3107
Satisfaction (D_6)	0.1942	D61 D62 D63	0.1152 0.4480 0.4367
Usefulness (D_7)	0.1787	D71 D72 D73	0.3851 0.2973 0.3177

Table 12. Weight vectors of the key dimensions and measuring items

users with global resources and services for study, reference and research. This shows a growing trend to be at par with the best libraries in the world. Developing a usable and effective library website is challenging task to success, maintaining and redesigning a website to meet the constantly changing user needs is a seemingly impossible task. Thus usability testing is expected to achieve this task as it not only supports identifying interface problems but also helps developing ways and means that would solve those problems. The available literature is attested that there is no any fixed criterion for usability evaluation process because many of the prior researches had discussed it in different aspects. In addition, heuristic evaluation methods, user surveys, and user observations were also used to evaluate the usability of library websites as well as different type and number of usability dimensions was undertaken for measurement development.

We have identified and validated a major measurement instrument dimensions and their measurement items for usability evaluation specific to library websites in Sri Lanka from our previous study. This study attempted to assess and prioritize relative weightings of the key dimensions and measuring items to ensure successful implementation of library website usability index system. Herein, the FAHP technique was used to determine the relative importance weights of the usability dimensions and measuring items. The process consists of four successive stages: an empirical data collection stage where a committee of experts in the internet and information technology sector filled in pair-wise comparisons of the importance of the key dimensions and all measuring items at the corresponding level with respect to the upper level dimensions with the help of questionnaires. In the comparison stage, the fuzzy comparison matrices of experts at the corresponding levels were build. At the validation stage, the consistencies of the pair-wise comparison matrices were measured to assure a certain quality level of a decision. Finally, a computation stage where a FAHP approach based on the extent analysis method was used to get the key dimensions and measuring items weights.

The overall perceived weightings of the seven dimensions of library website usability evaluation are presented in Figure 3. According to the results, the usability dimension of satisfaction is regarded as the most important with 19.42% in comparison with the rest of dimensions. This shows that the system should be pleasant to use, so that users are subjectively satisfied when using it. However, the accessibility was regarded as the least important dimension.

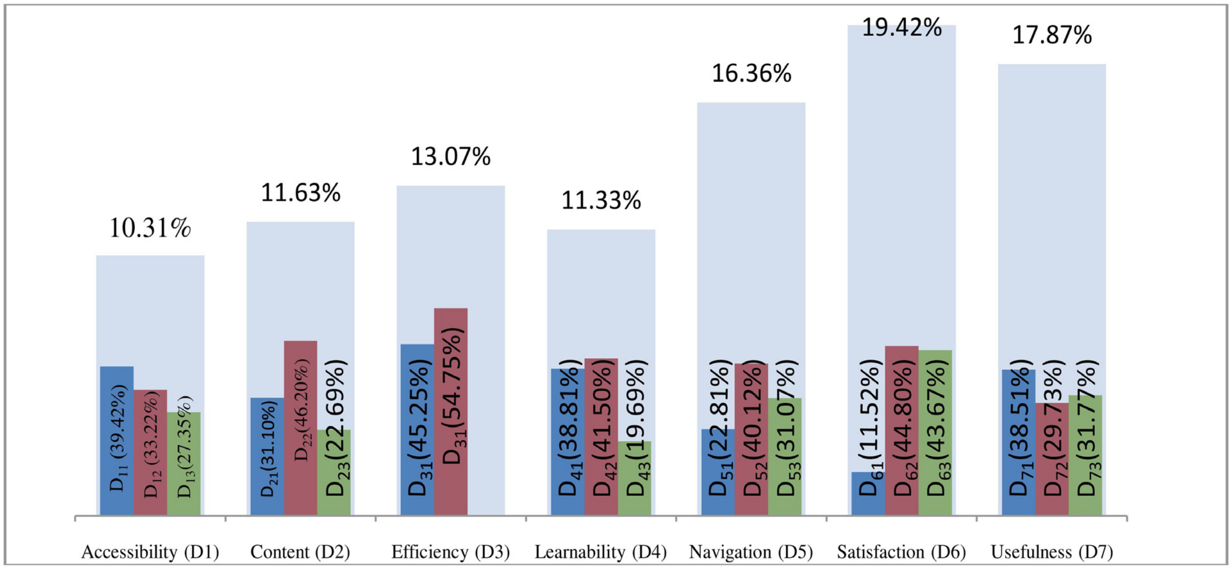


Figure 3. Overall perceived weightings of the dimensions and measurement items of library website usability evaluation model

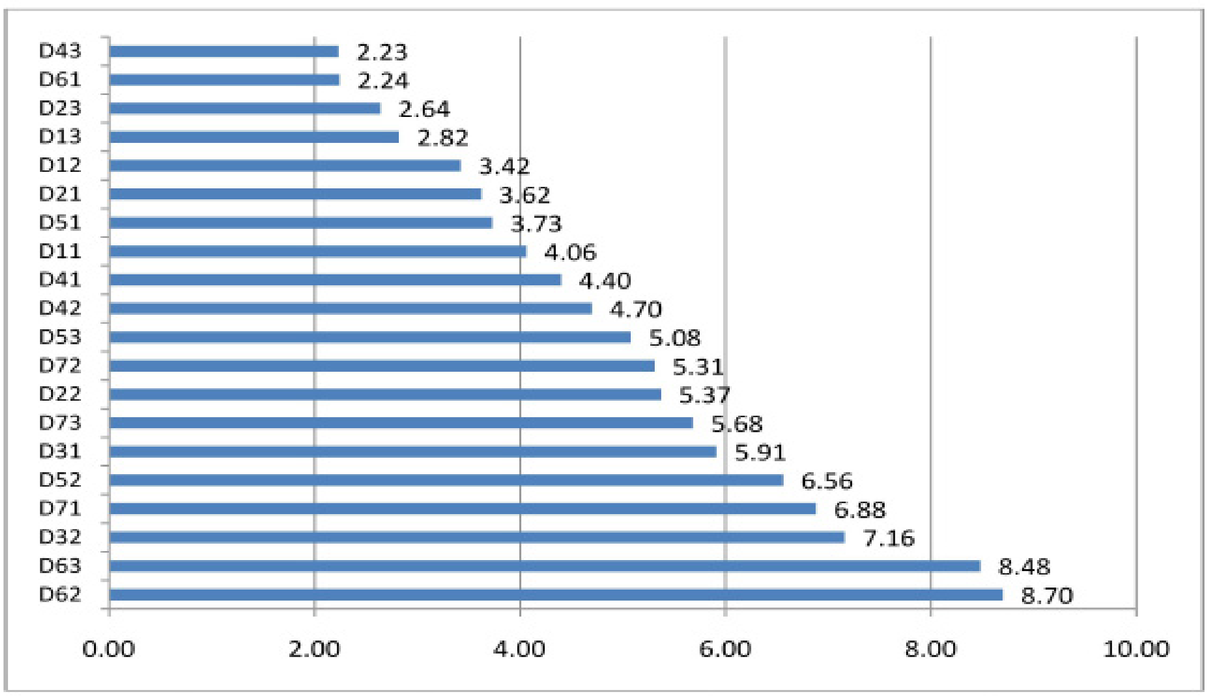


Figure 4. Cumulative contribution of measurement items of dimensions of library website usability evaluation model

Figure 4 illustrates the cumulative contribution of measurement items of dimensions of library website usability in decision-making at the second level in descending order of importance. According to the results as presented, the top 7 of the 20 measurement items assessed accounted for 49.37 percent of importance in their decision-making process. First two ranks belong to the usability dimension of satisfaction. Meanwhile, ranked third and sixth is the usability dimension of efficiency and ranked fourth and seventh is the usability dimension of usefulness.

Furthermore, the results of the study provide a strong contribution to design a library website and further evidence that website usability, as related to its design, is an important factor in the user's intention to use of the website while the motivation of the study was to better understand of relational importance of website usability dimensions and its role in a user's acceptance level of a website. Libraries can revise their websites according to the most important dimensions of web usability and then can increase volume of user transactions to the website. Website usability measuring instrument allows librarians to establish standards by evaluating the usability level of their websites and compare them with their relatives. Therefore, employing valid and reliable research instruments to measure website usability is vital for both staff and users of libraries. Finally, Forrester's research [38] has found that 50 percent of potential attraction of website can lose if users cannot find what they are searching for while when users' first experience is unsuccessful, then 40 percent of users do not revisit the website again.

7. Conclusion

A significant understanding of awareness and willingness of users cannot be done without a proper investigation of website usability while usability evaluation is a useful tool to keep up the quality of websites. The present study aimed to confer with our previous study that have identified and validated a major measurement instrument dimensions and their measurement items for usability evaluation specific to a library websites in Sri Lanka in order to ascertain and prioritize relative weightings of the key dimensions and measuring items to ensure successful implementation of library website usability index system with reasonable and objective factor weights. The immediate goal of this study was to investigate the perception on the priority of the key dimensions and measuring items from the viewpoint of experts. Based on the obtained results, the perceived relative importance weights of seven dimensions together with 20 measuring items were determined using the extent analysis fuzzy AHP technique.

The main contribution of this study is that it leads a technique for calculating the relative importance of dimensions and measuring items influencing library website usability by scientifically comparing with each other. The technique has capabilities to perform effective results with easy computations than the experts' assignation of the absolute priorities of each factor. Furthermore, the study used fuzzy multi-criteria evaluation methodology under a fuzzy environment to avoid uncertainty, ambiguity and loss of data, and difficulties faced in assessment cycle while all pair-wise comparisons which are in linguistic scale were converted into triangular fuzzy numbers for making uniform consensus of the decision makers. The findings of this study can be considered as indicators that provide necessary information about priority listing of dimensions for the web designers to design library websites more systematically and effectively. Therefore, the results of this study can be of benefit to the libraries that are trying to implement or improve quality of their websites because recognition of the user's priorities may reveal critical areas leading to the development of a more effective user-oriented website. In the next phase of this research, the authors plan to continue working with the obtained relative weightings of the key dimensions and measuring items to develop a library website usability evaluation framework based on the combination of fuzzy AHP and comprehensive evaluation method.

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