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ITJ

ISSN 1812-5638

INFORMATION TECHNOLOGY JOURNAL

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

OPEN ACCESS Information Technology Journal

ISSN 1812-5638
DOI: 10.3923/itj.2017.35.43

Research Article
Analytic Hierarchy Process (AHP) Based Model for Assessing Performance Quality of Library Websites

Ramanayaka Kokila Harshan, Xianqiao Chen and Bing Shi

School of Computer Science and Technology, Wuhan University of Technology, Hubei, China

Abstract

Background: Active presence of library websites on the internet is becoming a hallmark of academic networks commitment to facilitate the community to access the knowledge repositories around the world. For insightful planning towards a strong internet based information delivery and communication, there is a need for continuous monitoring of websites status. Therefore, it is important to set up a scientific and implementable index system for the purpose of evaluation of website performance quality which should lead the construction of website to a user friendly and informative level. Building on this need, this study engaged in a scientific discussion on feasibility of Analytical Hierarchical Process (AHP) approach based on multi-criteria decision making methodology and real world application to evaluate performance quality of library websites. **Materials and Methods:** The model was developed on the basis of a conceptual framework, which consisted of eight quantitative quality attributes identified from an extensive literature review as well as discussions with local experts. This study employed the AHP approach to measure the performance quality of library websites. **Results:** A case study was used to identify the feasibility of the proposed model. The results indicated that the model developed was more scientific, simple and comprehensible in concept, efficient in computation and robust in modeling human evaluation processes. The results suggested that each attributes constitutes differently to evaluate the performance of each website which will help decision-makers to know what improvements are needed to enhance the effectiveness and the final relative weights of each alternative at the last level of the hierarchy will lead to commend the best option. **Conclusion:** It is expected that this study may serve as a tool for libraries to evaluate the strengths of their online presence and plan to improve their status on the web. The research approach, criteria and their relative impact provide useful information to monitor the effectiveness of the current websites and provide strategic suggestions to develop enhanced websites. Future studies can adopt fuzzy multi-attribute approaches to evaluate the effectiveness of websites. The results of future studies can then be compared with that of those presented in this study.

Key words: Decision support systems, usability, library website ranking, website quality, AHP, university library, human computer interaction

Received: September 03, 2016 Accepted: November 17, 2016 Published: December 15, 2016

Citation: Ramanayaka Kokila Harshan, Xianqiao Chen and Bing Shi, 2017. Analytic Hierarchy Process (AHP) based model for assessing performance quality of library websites. Inform. Technol. J., 16: 35-43.

Corresponding Author: Ramanayaka Kokila Harshan, School of Computer Science and Technology, Wuhan University of Technology, Hubei, China

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Internet has reformed the lifestyle and its usage has increased to a great extent in recent times. Libraries have also followed the same trend with active online presence, which becomes a hallmark of libraries commitment to facilitate the community to access the knowledge repositories from around the world. In order to achieve this service level, libraries make available e-journals, e-books, e-databases, digitized reading collections, online catalogs, virtual information about the library, establishing web 2.0 services and enabling online feedback and requests through their websites. Prospective benefits of an effective website existence include greater research impact, attracting visitors, media interest and serving services on time. In this study, it is logical to investigate measures of the effectiveness of websites, both to study the communication activity that they represent and to build useful evaluation metrics[1]. Therefore, to keep up with this situation, libraries need to develop informative and rich content websites, continuously monitor their websites; performance and keep them update with the fast changing nature of the technology[2].

As results of the above requirements, it is necessary to provide a method to evaluate the performance quality of websites which include various technological and logical factors. Each definition of performance quality from literature leads to lists of criteria about what constitutes a good quality website and how to measure the performance[3-5]. Therefore, it is important to set up a scientific and implementable index system for the purpose of evaluation of website performance quality which should lead the construction of website to a user friendly and informative level. This study employed the Analytical Hierarchical Process (AHP) mathematical approach to measure the performance quality of library websites. In this study, it is proposed a modified approach based on appropriate quantitative criteria for measurement of library website performance quality. This study aimed to build an understandable and applicable model for measuring library website performance quality by using the Sri Lankan university library websites as a case study. By establishing a feasible model, it is expected that organizations especially in libraries in general can better understand whether a given website can meet the expectations of its users, they serve in order to improve their satisfaction level.

In recent decades, several researchers have focused on the evaluation of different decision making problems by employing AHP mathematical models and a variety of alternative approaches to performance quality evaluation have been proposed in previous studies[6]. Ivory and Hearst[7] proposed a new methodology called Web Tango for check website quality which proposed to help non-professional designers to develop their sites using quantitative measures of the navigational, informational and graphical aspects of a website. Chang and Hon[8] developed an enhanced equation to evaluate the performance of a website via a queuing network model and Chang and Chuang[9] introduced a mobile agent mechanism to evaluate performance monitoring of remote websites with applying and analyzing by a simplifying example. Signore[10] proposed a quality model along with a set of characteristics relating internal and external quality factors to measure the quality assessment of websites. Later, Liu *et al.*[11] stated that in order to measure the customer satisfaction while purchasing through online system, eight constructs were significant to determine the website quality and Li and Chen[12] proposed Fuzzy Analytical Hierarchy Process (FAHP) method to evaluate the online bookstores by presenting a case study to demonstrate how the approach can help in evaluating the performance quality of online bookstore more understandable. Guangjin *et al.*[13] built a binary relative performance index with binary relative evaluation method to measure Chinese provincial government websites performance quality by setting past performance as the reference standard for each website. In the same year, Li and Le[14] proposed a dynamic performance evaluation model based on the theory of managerial effectiveness for measure Chinese provincial government websites performance quality. Wu and Ren[15] evaluated the effectiveness of the tourism e-business websites in China with the purpose-value framework of evaluation on the content delivery performance while Buyukozkan *et al.*[16] built a model to evaluate the quality of e-learning websites by adopting an axiomatic design based approach for fuzzy group decision making context.

Dominic and Jati[5] proposed a methodology for determining and evaluating the best Asian airline website based on many criteria of website quality, consist of Linear Weightage Model (LWM), AHP, FAHP and one New Hybrid Model (NHM). This NHM was implemented using combination of FAHP and LWM. Rekik and Kallel[17] presented a quality assessment model based on multiple criteria decision making in order to measure the performance of dynamic institutional websites. Khan and Dominic[4] checked the Asian airlines website quality using 11 criteria chosen from the previous studies. The AHP was used to evaluate the website quality of each airline and the results suggested the best airline operates in Malaysia. In the same year, Presley and Fellows[18] in a study entitled "An AHP model for evaluating and comparing financial website usability" presented a model based on the Microsoft usability guidelines and the AHP to evaluate usability of websites. The developed model was applied to identify the usability level of financial portals. Dominic and Khan[3] measured the performance quality of 4 airline websites that operated very frequently in Malaysia using 11 criteria and the AHP and FAHP approaches were used to measure and compare the quality of these websites. Hong[19] proposed the AHP based method for relative objective and quantitative evaluation in system engineering to carry on the evaluation of sports management system with simple calculations. Faustina and Balaji[20] evaluated the quality of online services given by university websites in Chennai, India using criteria adopted from literature and AHP techniques were employed to evaluate the quality of the websites.

In summary, the literature point out the fact that the importance of assessing performance in websites and identify several dimensions along with which websites can be evaluated for performance quality. Furthermore, there are no studies in the literature that analysis the quality of websites in Sri Lankan university library websites. As a contribution to addressing this need, this study was aimed to explore a practical framework based on appropriate criteria of website quality and AHP techniques to performance quality evaluation of university library websites in Sri Lankan context.

MATERIALS AND METHODS

Proposed model for designing an AHP preference library website performance quality assessing system: The AHP uses a mathematical technique which enables people to make decisions involving several concerns including planning, setting priorities, selecting the best among a number of alternatives and allocating resources[21].

Identification of criteria that effect to the performance of website: To identify the criteria that affect the quality of a website, the researchers conducted an extensive literature review of academic journal and conference proceedings and web documents along with discussions with local experts about the suitability of them in Sri Lankan context. Based on the literature review and discussions, eight criteria, which include the load time, page size, number of items, page speed, broken links, response time, mark-up validation and design optimization were selected to measure the quality of library websites and subjected to a review by the local experts to determine the relative importance of each criterion to the Sri Lankan context[3,4,10,22].

The computational procedure of the AHP preference library website performance quality evaluation model consists of following process.

Step 1: Construct hierarchical structure: The evaluation procedure starts at the determination of the problem's specification for its multi-criteria perspectives and identified set of criteria, C_j (j = 1, 2,..., 8), we concern about and how many potential alternatives, A_i (i = 1, 2,..., n). The problem is decomposed into a hierarchical structure as depicted in Fig. 1.

Step 2: Collect quantitative data for identified criteria in each alternative: The online web diagnostic tools are shown in Table 1 which can be used to collect quantitative data for identified criteria in each alternative have been identified from an extensive literature review.

Step 3: Normalized collected data: The algorithm starts with assessing a qualitative or quantitative assessment x_{ij} (i = 1, 2,..., n, j = 1, 2,..., m) called as the performance rating of each decision alternative A_i (i = 1, 2,..., n) with respect to each criterion C_j (j = 1, 2,..., m) using a scale of 1-9 where 1 represents equality of criteria importance and 9 represents the highest or the superior value that can be given to each criterion. Usually decision criteria have different units of measure and different range of values so any comparisons among those criteria are not logically acceptable. By applying the data normalization concept, all the criteria will be having weights in between 1 and 9 instead of a variety of measurement units and value ranges and then the comparisons can simply be made[22].

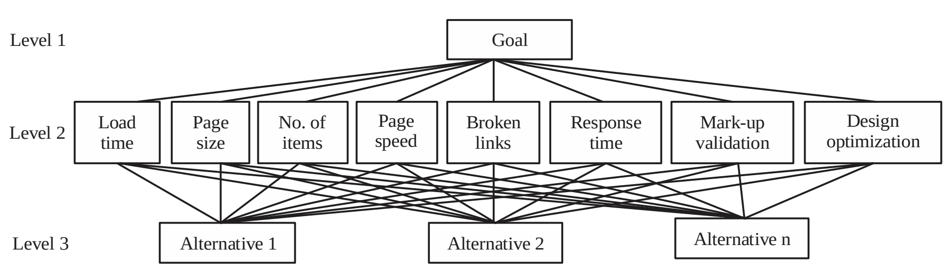

Fig. 1: Decision hierarchy of the problem

Table 1: Online web diagnostic tools

Ref.	Criteria	Web diagnostic tool
C1	Load time	tools.pingdom.com
C2	Page size	tools.pingdom.com
C3	No. of items	tools.pingdom.com
C4	Page speed	tools.pingdom.com
C5	Broken links	www.duplichecker.com/broken-link-checker.php
C6	Response time	www.websitepulse.com
C7	Mark-up validation	validator.w3.org/#validate_by_uri
C8	Design optimization	www.webpagetest.org

As a result, a normalized pair-wise matrix can be obtained as Eq. 1:

$$X = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_n \end{array} \begin{bmatrix} C_1 & C_2 & \cdots & C_m \\ x_{11} & x_{12} & \cdots & x_{1m} \\ x_{21} & x_{22} & \cdots & x_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ x_{n1} & x_{n2} & \cdots & x_{nm} \end{bmatrix} \quad (1)$$

Step 4: Calculate the relative weights for alternatives in each criterion: The corresponding criteria weights (w_j) can be calculated with the application of the pair-wise comparison matrix as Eq. 1 and 2:

$$w_j = \frac{\sum_{p=1}^{m} \tilde{x}_{jp}}{\sum_{p=1}^{m}\sum_{q=1}^{m} \tilde{x}_{pq}} \quad (2)$$

where, j is 1, 2,......, m.

Step 5: Construct pair-wise comparison matrixes for each criteria: Once these have been obtained, in terms of each criterion, the pair-wise comparison matrices that determine the preference of each alternative over another are calculated by fixing the relevant criteria that find the pair-wise comparison matrix and then the fixed value is divided with the rest of the values in the column from the normalized table (Eq. 1). The pair-wise comparison A_j, which related to the criteria j, in which the element a_{ij} of the matrix is the relative importance of the ith alternative with respect to the jth alternative, could be calculates as Eq. 3:

$$A_j = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_n \end{array} \begin{bmatrix} A_1 & A_2 & \cdots & A_n \\ x_{1j}/x_{1j} & x_{1j}/x_{2j} & \cdots & x_{1j}/x_{nj} \\ x_{2j}/x_{1j} & x_{2j}/x_{2j} & \cdots & x_{2j}/x_{nj} \\ \vdots & \vdots & \ddots & \vdots \\ x_{nj}/x_{1j} & x_{nj}/x_{2j} & \cdots & x_{nj}/x_{nj} \end{bmatrix} \quad (3)$$

Step 6: Calculate the relative weights for each alternatives in each criterions: The corresponding criteria weights (W_i^j) for ith alternative in jth criteria can be calculated by multiplying the pair-wise comparison matrix (A_j) by itself as Eq. 4 and 5 and then dividing the row sum by the row totals of the resultant matrix as Eq. 6:

$$a_{pq} = \sum_{k=1}^{n} (A_{pk} \times A_{kq}) \quad (4)$$

where, p, q is 1, 2,..., n.

$$A_j \times A_j = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_n \end{array} \begin{bmatrix} A_1 & A_2 & \cdots & A_n \\ a_{11} & a_{12} & \cdots & a_{1m} \\ a_{21} & a_{22} & \cdots & a_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nm} \end{bmatrix} \quad (5)$$

$$W_i^j = \frac{\sum_{p=1}^{n} a_{ip}}{\sum_{p=1}^{n}\sum_{q=1}^{n} a_{pq}} \quad (6)$$

where, i is 1, 2,......, n.

Step 7: Calculate the overall performance index: The results of the previous steps provide a weight for each criterion along with a weight for each alternative against each criterion. The score obtained for each website across each criterion was calculated by multiplying the weight of each criterion with the weight of each website and the final score was calculated by adding all the criteria values together using Eq. 7. Website which has the highest score is suggested as the best website according to the used criteria.

$$\text{Final score of ith website} = \sum_{j=1}^{m} (WC_j \times WA_j) \quad (7)$$

where, m is the number of criteria, WC_j is the weight of jth criteria and WA_j is the weight of ith website in jth criteria.

RESULTS

Case study: In results, we presented a case study for assessing the performance quality of university library websites in Sri Lanka to illustrate the applicability of the model developed.

Selection of universities: The universities chosen for the case study are the 15 state universities in Sri Lanka[23]. The URLs of these university library websites were identified by visiting the parent university websites and verify that these URLs were

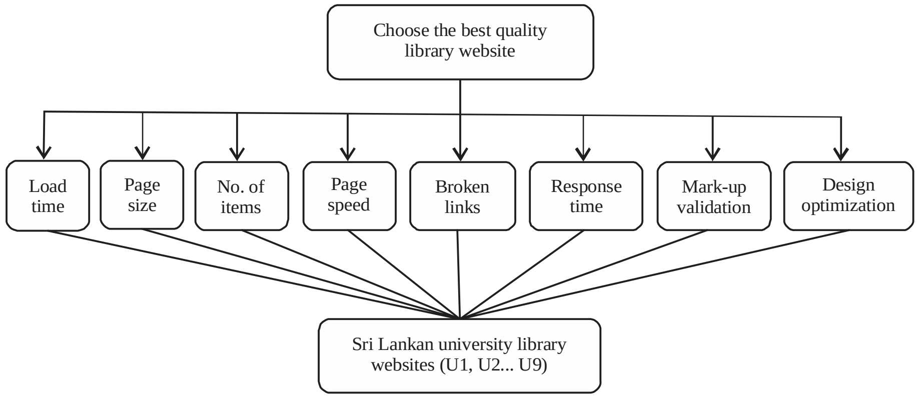

Fig. 2: AHP model of Sri Lankan university library websites

Table 2: Website URLs of university libraries in Sri Lanka

Ref.	Library	Home URL
U1	Sabaragamuwa University of Sri Lanka	http://www.lib.sab.ac.lk
U2	The Open University of Sri Lanka	http://lib.ou.ac.lk
U3	University of Colombo	http://www.lib.cmb.ac.lk
U4	University of Jaffna	http://www.lib.jfn.ac.lk
U5	University of Moratuwa	http://www.lib.mrt.ac.lk
U6	University of Peradeniya	http://www.lib.pdn.ac.lk
U7	University of Ruhuna	http://www.lib.ruh.ac.lk
U8	University of Sri Jayewardenepura	http://lib.sjp.ac.lk
U9	University of the Visual and Performing Arts	http://lib.vpa.ac.lk

Table 3: Original data for each library website

Criteria	U1	U2	U3	U4	U5	U6	U7	U8	U9
Load time (sec)	5.96	10.78	5.79	7.34	4.35	4.35	9.20	7.30	7.35
Page size (No.)	761.20	2900.00	1600.00	478.00	2800.00	2800.00	2700.00	3500.00	4700.00
No. of items (No.)	22.00	75.00	103.00	49.00	123.00	137.00	53.00	104.00	68.00
Page speed (No.)	76.00	88.00	90.00	75.00	61.00	86.00	81.00	87.00	75.00
Broken links (No.)	13.00	1.00	10.00	5.00	2.00	37.00	16.00	1.00	5.00
Response time (sec)	1.26	1.54	2.70	0.83	1.95	2.10	3.44	2.38	2.13
Design optimization (%)	58.00	98.00	66.00	71.00	58.00	98.00	33.00	63.00	98.00
Markup validation (No.)	6.00	22.00	35.00	109.00	20.00	16.00	28.00	24.00	46.00

in separate domains for these library website and subject directory indexed. In here, it is examined that only 9 university libraries were qualified with the above conditions. So this study examined the websites of 9 university libraries in Sri Lanka which are listed in Table 2, together with their corresponding URLs.

The hierarchical structure of evaluating performance quality of Sri Lankan university library websites can be drawn as the following Fig. 2.

The original data for each criterion gathered as presented in Table 1. The data were collected on three different occasions. The first one was on March, 2016 and the second was on May, 2016 while the third data was on July, 2016. As data was collected on different periods of time so the average value of each criterion is presented in the Table 3.

Step 3: Normalized collected data: Table 4 was designed to express the interval values of each region with respect to each criterion.

The weights for each criterion along with a weight for each alternative against each criterion and the final scores of web presence in each alternative were determined by applying Eq. 1-7 and the results are shown in Table 5.

The website which has the highest score is proposed as the best website. Table 5 shows that the alternative with highest weight (0.1323) is University of the Visual and Performing Arts library website. University of Peradeniya library website is the second and Sabaragamuwa University of Sri Lanka library website is the last ranked. Furthermore, according to the results generated from the proposed approach, decision makers have a chance to compare with other alternative according to each criterion also.

Table 4: Interval values of regions with respect to each criterion

Criteria	1	2	3	4	5	6	7	8	9
Load time	$\leq$4.0	4.0-4.5	4.5-5.0	5.0-5.5	5.5-6.0	6.0-6.5	6.5-7.0	7.0-7.5	$\geq$7.5
Page size	$\leq$500	500-1000	1000-1500	1500-2000	2000-2500	2500-3000	3000-3500	3500-4000	$\geq$4000
No. of items	$\leq$25	25-40	40-55	55-70	70-85	85-100	100-115	115-130	$\geq$130
Page speed	$\leq$50	50-55	55-60	60-65	65-70	70-75	75-80	80-85	$\geq$85
Broken links	$\leq$1	1-5	5-10	10-15	15-20	20-25	25-30	30-35	$\geq$35
Response time	$\leq$1.0	1.0-1.3	1.3-1.6	1.6-1.9	1.9-2.2	2.2-2.5	2.5-2.8	2.8-3.1	$\geq$3.1
Design optimization	$\leq$30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	$\geq$100
Markup validation	$\leq$10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	$\geq$80

Table 5: Final evaluation results

Criteria (Weight)	U1	U2	U3	U4	U5	U6	U7	U8	U9
Load time (0.1478)	0.0132	0.0237	0.0132	0.0211	0.0053	0.0053	0.0237	0.0211	0.0211
Page size (0.1266)	0.0043	0.0165	0.0091	0.0027	0.0160	0.0160	0.0154	0.0199	0.0268
No. of items (0.1240)	0.0026	0.0132	0.0185	0.0079	0.0211	0.0237	0.0079	0.0185	0.0106
Page speed (0.1794)	0.0185	0.0211	0.0237	0.0185	0.0106	0.0237	0.0211	0.0237	0.0185
Broken links (0.0844)	0.0106	0.0026	0.0106	0.0079	0.0053	0.0237	0.0132	0.0026	0.0079
Response time (0.1135)	0.0053	0.0079	0.0185	0.0026	0.0132	0.0132	0.0237	0.0158	0.0132
Design optimization (0.1372)	0.0106	0.0211	0.0132	0.0211	0.0106	0.0211	0.0053	0.0132	0.0211
Markup validation (0.0871)	0.0026	0.0079	0.0106	0.0237	0.0079	0.0053	0.0079	0.0079	0.0132
Total value	0.0676	0.1141	0.1173	0.1056	0.0899	0.1321	0.1183	0.1228	0.1323
Rank	9	6	5	7	8	2	4	3	1

DISCUSSION

The major objective of the study was to proposed a new methodology in order to measure performance quality of a library website by applying AHP tools based on quantitative data with a method for evaluating it. The evaluation indicates the extent to which each library has successfully represented itself on the internet. In general, the successful presence of a website on the web can be attributed to possessing appropriate number of web pages that influence their visibility through search engines. In literature relevant to the performance quality of websites, most studies were analyzed by means of personal knowledge, experience, judgment and statistical software[2,7,8,24-28]. The findings of this study regarding the performance quality of website corroborate the findings of the study by Roy *et al.*[29] which showed that the AHP proves to be the reliable way for a user to make a decision for choosing a best website that fulfills user satisfaction. Unlike Roy *et al.*[29] study, this study used mathematical calculation approach to find out the relative weights for alternatives in each criterion with the application of pair-wise comparison matrix instead of pair-wise comparisons survey method from experts. This will avoid the bias of the human involvements and the whole process can be carried out within a shorter period of time. Moreover, the model developed can adequately handle the inherent uncertainty and imprecision of the human decision making process and provide the flexibility and robustness needed for the administrators to better understand the decision problem and their decision behaviors. Akgul[30] used various dimensions of quality in order to measure website's various components where each component was measured by the specific test online and physically visiting the sites separately with applying more efforts by using only a simple statistical calculation method to obtain the final results. However, in this particular study, it has been used AHP mathematical tools that provide faster and better results resulting better decision making, flexibility and ability to check inconsistencies while paving way for handling hierarchies of criteria with quantitative data[31]. Yaokumah *et al.*[32] used content analysis method which entailed gathering of similar data within the scope of specific concepts and themes and arranged results in different categories not in final numerical value for each website performance. Instead, this particular study took the final relative values of each alternative against each criterion and also the final relative values of each alternative at the last level of the hierarchy that will lead to commend the best option. This will help decision makers to know what improvements are needed to enhance the effectiveness of their website. Kaur *et al.*[33] investigated the quality of websites of Punjabi and Hindi newspapers with the help of third party software tools considering the limited measurement criteria that gives results from those tools. In contrast, this study conducted an extensive literature review of academic journal and conference proceedings and web documents to identify the best criteria along with discussions with local experts about the suitability of them in library context. Jati and Dominic[34] conducted the quality evaluation study of e-government websites using a series of online diagnostic tools to examine 6 dimensions of quality where each dimension was measured by using internationally guided quality standards presented separately. In this study, it has been proposed a systematic procedure of the AHP preference model in the multi-criteria group decision making environment to compare the constructs within each alternative and expected that this model may provide an effective and scientific measurement, not only for assessing the performance quality, but also for other services as well. Therefore, this procedure yields an accurate solution with a high degree of consensus.

This study provides several important findings for both researchers and practitioners. From theoretical perspective, this study first attempts to provide a comprehensive investigation of the multifaceted dimensions of performance quality of websites. Reliable and scientifically validated instruments of performance quality of websites enable developing consensus among researchers on how to assess performance enabling coherent examining of the structure and dimensionality of performance. There are noteworthy uses i.e. firstly, the instruments can be utilized in future website usability studies while ensuring direct compatibility of accumulated findings. Secondly, the proposed model enables the decision makers to make both quantitative and qualitative assessments as it uses more understandable scale to compare factors and simple mathematical calculations to get important weights. This study also has several practical implications. The proposed model assists practitioners to identify performance quality dimensions where they need to put extra resources for increasing performance level. For instance, the measurement items we developed can be used by organizations to establish benchmarks by evaluating the performance level of their own websites and compare them with their competitors. In addition, the newly identified methodology permits website designers to better understand complex interactions between constructs and gauge the true amount of contribution of each construct. By closely observing dynamic interactions between constructs, organizations can successfully allocate their limited resources to the more impactful factors. Finally, the model can be used as a standard website design guideline which helps to develop usable websites across library domains.

An empirical study of a performance quality evaluation of Sri Lankan university library websites was conducted using the model developed. It shows that the model was favorable for solving practical multi-criteria analysis problems involving quantitative data. A simple but comprehensive concept model has been used with an efficient computation method. For further research, the fuzzy techniques can be applied and their results can be compared with that of proposed model. The work can be further extended for evaluation of website of any organization by identifying the important parameters that need to be considered for designing a website.

CONCLUSION

This study proposes an AHP preference model based on multi-criteria decision making methodology and real world application to evaluate performance quality of library websites. The proposed model can produce effective ranking results with easy computation. The underlying concept of this approach is simple, easy to understand and easy to handle. The computation process included with a systematic procedure and applying this procedure can get an accurate solution with a high degree of consensus. The main criteria that affect the performance of a website and the quantitative data collection strategies were derived from reviewing previous studies as well as discussions with local experts.

Finally, the case study shows that the approach is applicable as an evaluation technique for library websites and may provide an effective and scientific measurement. The final relative weight of each alternative at the last level of the hierarchy will lead to commend the best option and the final results will help decision makers to know what improvements are needed to enhance the effectiveness of their website. Although the proposed approach is stated as a model for performance quality evaluation with maximum effectiveness, it can also be utilized in different sectors with some modifications in criteria. Future studies can adopt fuzzy multi attribute approaches to evaluate the effectiveness of websites. The results of future studies can then be compared with that of those presented in this study.

SIGNIFICANCE STATEMENTS

The outcomes of this study would redound significantly to the benefit of technological society in the area of web design and its performance evaluation. In addition, it would also contribute towards indicating the extent to which each library has successfully represented itself on the internet and provides the basis for future research in web evaluation, usability and other related areas.

The contributions of this study to knowledge are at least:

- An identification of generic criteria for performance quality of a website
- An explanation of how these generic criteria can be applied to web design particularly the design of library websites

- A framework of how these criteria can be used to benchmark and evaluate websites
- The proposed model can be used by both technical and non-technical users and web designers and it can be carried out within a short period of time
- It can be used to identify the level of performance of one's website against those of competitors

ACKNOWLEDGMENT

The authors would like to convey their sincere gratitude to all those who have significantly contributed towards the completion of this study.

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