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Research Article
Application of Multilevel Grey Comprehensive Assessment on the Technological Evaluation of Web Presence

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Abstract

Background and Objective: Websites are mainly used as a virtual image and promotional platform of the organization that display all information and services given by them. There is a necessity for successive monitoring the condition of the website to give a strong internet-based information delivery and communication to the community while web presence considers as a strong indicator of the performance and reputation of a website and it is a good indicator to find out where the specific website is on the web, how good the content is and how it relates to the other parties. The objective was to engage this study in a scientific discussion on feasibility of a multi-level grey evaluation model based on linguistic terms characterized by interval grey numbers to evaluate webometric status of websites which include various multidimensional technological and logical factors. **Materials and Methods:** The study conducted an extensive literature review along with discussions with local experts to identify the criteria that affect to the web presence of a website and how to measure these criteria. The model for evaluating web presence of websites was developed based on the grey theories while research into the mathematics underlying the grey theories using books and studies published research papers. **Results:** A case application was carried out in assessing the web presence of university library websites in Sri Lanka to make the model more understandable. The results declare that the model is easy to use, understandable, robust as well as scientific than the human evaluation processes and other traditional ways. The results suggested that each attribute constitutes differently to evaluate the web presence 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, could lead to commend the best option. **Conclusion:** 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.

Key words: Grey numbers, web presence, webometric, website ranking, website usability

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

INTRODUCTION

In line with growing pace of advancement of internet technology, the World Wide Web found to be as an imperative provider of public interface for researchers and information seekers all over the world. It is regarded as a key that opens doors to the knowledge repositories of academic work. Furthermore, it dramatically changed the traditional ways of information collecting, evaluating, storing and disseminating strategies used by information centers together with saving money, time and created new opportunities and achievements for promoting social and cultural interactions with updated information[1]. Presently, active presence of academic networks on the internet is becoming a hallmark of their commitment to facilitate the community to disseminate quality educational and research information with easier way. Prospective benefits of an effective website existence include greater research impact, attracting visitors, media interest and serving services on time among the higher level of scientific production and scientific development in human communities. Therefore, accordingly to the fast changing environment of the technology, academic networks need to develop instructive and well content websites as well as continuously monitor and update their websites performance up-to-date[2,3].

Resulting on the above requirements, there was a need to generate a method to evaluate the web presence status of websites which include various technological and logical factors. Herein, the criteria affective to the web presence of websites and how to measure these criteria can be identified from past researches available in the literature[4-6]. Therefore, it was important to set up a scientific and implementable index system for the purpose of evaluation of web presence status of websites which should lead the construction of a user friendly and informative website.

Web presence can be considered as a strong indicator of the performance and reputation of a website and it was a good indicator to find out where the specific website was on the web, how good the content was and how it relates to the other parties. Moreover, web presence creates a strong and positive corporate image on the internet and to convert this into attracting visitors to the website and encouraging them to return[7]. Additionally, web presence measures web attributes such as website quality, visibility, usability and convenience[8-10].

Traditional web presence evaluation methods: In literature relevant to the web presence, most studies were analyzed by examining web impact factor (WIF) and web indicators of science, innovation and research (WISER) indicators while these two approaches have their strength and drawbacks together with one of the major key limitation was the lack of mathematical model of evaluation. The quality of information provided by the website together with the total size of a website was represent from the WIF and is generally defined as the ratio between the number of links received and the total number of web pages of a particular website[11]. There are three types of link namely, outlinks or external links which are HTML code on the website which allows site visitors to access other websites, inlinks or backlinks which are hyperlinks on someone else's website that direct visitors to your site and self-links which are navigational links used in a website to direct users from one page to another page within the site. However, Noruzi[12] has expressed that self-links for the website under evaluation can provide ambiguous results, as the number of self-links can be manipulated by different means by site owners. For example, in some cases, self-link counts increase because of email addresses associated with websites, which is identified by the search engine as links to that specific domain. Therefore, self-links are less meaningful than inlinks since self-links can be used for navigation purposes rather than for endorsing the contents. In addition, inlinks create more visibility on the web and potentially more traffic to the site and better coverage by search engines together with higher ranking in search results[3]. WISER has taken the number of web pages in a website (size), number of external links it receives (visibility), the total number of academic files (rich files) and the total number of highly cited research papers (scholars) published on the website[13,14].

Multiple criteria decision making (MCDM) problems solving methods: However, in the past, several methods have been proposed to solve different multiple criteria decision making (MCDM) problems in different disciplines, the main ones being the linear weighting methods (LW), mathematical programming (MP) techniques, the analytic hierarchy process (AHP), the analytic network process (ANP), fuzzy AHP and grey theories. 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 uncertainty and imprecision linked with the mapping of a decision maker's observation to exact numbers. The ANP can be used to solve MCDM problems where in 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. Similar to fuzzy theory, grey theory is a multi disciplinary and generic theory that can also be applied to solve problems containing uncertainty and indetermination data. However, grey theory has more effective flexibility to deal with the fuzziness situation than fuzzy theory[15-19].

Factors affecting web presence: In the last few decades, several webometric studies have been conducted in different countries and a variety of alternative approaches to web presence evaluation have been proposed in previous works. Ingwersen[20] expressed that the external backlinks to websites as well as the number of web pages published on the websites, which are indexed by search engine and key indicators, can be used to measure the effectiveness of websites. Aguillo *et al*.[21] presented that results of cybermetric measurements can be used to identify the factors should improve to increase the visibility and rankings of the institutions. Furthermore Noruzi[12] expressed that a higher external backlinks would indicate more visibility and greater success of the website, both nationally and internationally, making the site more reliable and popular. Jeyshankar and Babu[22] expressed that the external backlinks represents the extent to which a website was linked to and by other sites like a citation count in the print materials. Furthermore, they proposed that higher the external backlinks count, the higher was the perceived reputation of the website and provides a quantitative tool for ranking, evaluating, categorizing and comparing websites. Vaughan and Thelwall[3] remarked that the external backlinks and page count can be used directly to measure effectiveness of the website or indirectly to provide a metric that may associate with important offline phenomena.

MCDM problem solving with grey theories case studies: However, a quick review of MCDM related problem solving models in outsourcing literature shows that many researches proposed methods based on grey theories to solve the MCDM problems because it's ability to analyze ambiguous real world problems. For example, a study by Li[23] has proposed a grey MCDM based conceptual infrastructure for evaluate e-commerce websites, Hou[24] has expressed that how to select a good IT/IS project applying grey theory with MCDM methods, He and Yanan[25] have developed the multi-level grey fuzzy comprehensive method to evaluate steam turbine safety levels, Liu *et al*.[26] have discussed the concepts, principles and components of grey system theory with its applications in science, Li *et al*.[16] proposed a grey based approach to select a supplier under an uncertain environment, Zhu and Chen[27] have established a evaluation index system based on grey theory and AHP to measure the user satisfaction of management information system, Bai *et al*.[28] have proposed a multi-level gray evaluation method to monitor the urbanization development status, Jadidi *et al*.[29] have proposed a grey TOPSIS concepts theory based model to select required suppliers, Wu *et al*.[30] have introduced a multi-level fuzzy-grey evaluation method to solve information security risk related problems with quantitative assessment, Wang *et al*.[31] have developed customer satisfaction index of B2C e-commerce enterprise adopting AHP and Grey theory.

Based on literature and the summarization of grey based evaluation systems at home and abroad, this study constructs the multilevel grey comprehensive method which used grey theory concepts to measure the web presence status of websites adopting with appropriate quantitative criteria. The paper aimed to build an understandable and applicable model for measuring website effectiveness by using the Sri Lankan university library websites as a case study. By establishing a feasible model, it was expected that organizations especially in academic networks, in general can better understand whether a given website meets the expectations of its users and serve in order to improve their satisfaction levels.

MATERIALS AND METHODS

Preliminaries

Grey theory: The grey system theory was introduced by Deng[32] in 1982 and it was mainly focus on problems which have poor information and small samples. Presently, the grey system theory was potentially applied in systems analysis, data processing, modeling and prediction, as well as in control and decision-making related fields because of its ability to deal with uncertain systems with partially known information through generating, excavating and extracting useful information from what is available[26,33]. A grey number can be described as an indeterminate number that take its possible value within an interval or a general set of numbers and an interval grey number (G) is represented by $\left[\underline{G}, \overline{G}\right]$ where, $\underline{G}$ is the lower bound of G and $\overline{G}$ is the upper bound of G that are real numbers and may be infinite value[34].

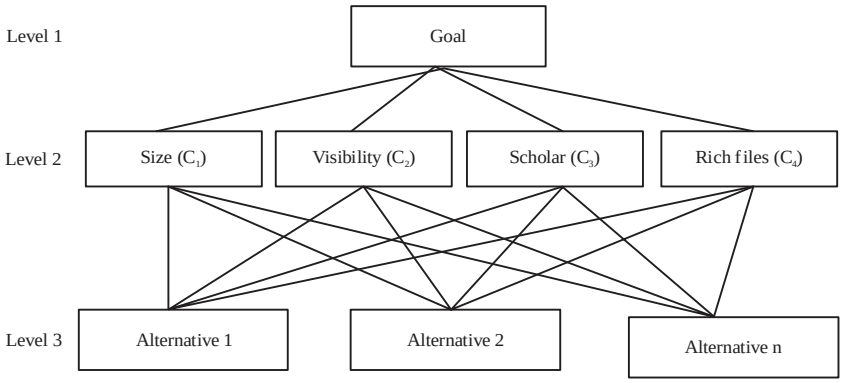

Fig. 1: Decision hierarchy of the problem

Table 1: conversion scale of interval grey number

Scale	Very poor	Poor	Fair	Good	Very good
G	[0, 1]	[1, 3]	[3, 4]	[4, 6]	[6, 7]

Operations in grey theory: Let, $G_1 = \left[\underline{G}_1, \overline{G}_1\right]$ and $G_2 = \left[\underline{G}_2, \overline{G}_2\right]$ be two grey numbers and then the basic operation laws can be defined as Li *et al.*[16]:

$$G_1 + G_2 = \left[\underline{G}_1 + \underline{G}_2, \overline{G}_1 + \overline{G}_2\right] \quad (1)$$

$$G_1 - G_2 = \left[\underline{G}_1 - \underline{G}_2, \overline{G}_1 - \overline{G}_2\right] \quad (2)$$

$$G_1 \times G_2 = \begin{bmatrix} \min\left(\underline{G}_1\underline{G}_2, \underline{G}_1\overline{G}_2, \overline{G}_1\underline{G}_2, \overline{G}_1\overline{G}_2\right), \\ \max\left(\underline{G}_1\underline{G}_2, \underline{G}_1\overline{G}_2, \overline{G}_1\underline{G}_2, \overline{G}_1\overline{G}_2\right) \end{bmatrix} \quad (3)$$

$$G_1 / G_2 = \left[\underline{G}_1, \overline{G}_1\right] \times \left[\frac{1}{\underline{G}_2}, \frac{1}{\overline{G}_2}\right] \quad (4)$$

The length of a grey number G is defined as:

$$L(G) = \left[\overline{G}, \underline{G}\right] \quad (5)$$

Furthermore, most researchers recommended a degree of grey possibility theory to compare the ranking of grey numbers, i.e.:

$$P\left\{G_1 \le G_2\right\} = \frac{\max\left(0, L^* - \max\left(0, \overline{G}_1 - \underline{G}_2\right)\right)}{L^*} \quad (6)$$

where, P is the possibility degree of G_1 and G_2 grey numbers and $L^* = L(G_1)+L(G_2)$.

Establishing multi-level grey comprehensive evaluation model: The main objective of this study is to define a grey evaluation model with a decision matrix, x_{ij}, where, i represents the criteria that effects to the web presence and j represents the alternatives, for evaluate webometric status of academic websites. Hence, the evaluation method usually should be consisted with construct hierarchical structure of the problem, use the appropriate ways to deal with the criteria and comprehensive evaluation approach.

The linguistic variables that facilitate the pair-wise comparison of all elements can be expressed in grey numbers by 1-7 scale as shown in Table 1[16].

Identification of criteria that effect to the web presence: The effectiveness of web presence depends on multiple criteria to cover the different aspects of presence. So, the study conducted an extensive literature review of academic journals, conference proceedings and web documents along with discussions with local experts to identify the criteria that affect to the web presence of a website. Herein, a set of four criteria namely, size, visibility, scholar and rich files were identified from the prior researches[2,13-14,21-22,35-45].

Construct hierarchical structure: After identifying a set of criteria, C_j (j = 1, 2, 3, 4) that affect to the web presence and the number of potential alternatives to be measured, A_i (i = 1, 2,....., n), then a hierarchical structure of the problem can be drawn as depicted in Fig. 1.

Collect data for identified criteria in each alternative: The study proposed to use Yahoo, Google and Google Scholar search engines and SEO CHAT application tool to collect quantitative data for identified criteria in each alternative. The two search engines and SEO CHAT application tool can be used to collect the number of web pages and the external links, while Google can be used to find the number of rich files

Table 2: Search syntax

Search engine	Visibility	Page count	Number of rich files
Google	link:www.lib.ruh.ac.lk -site:ruh.ac.lk	site: www.lib.ruh.ac.lk	site: www.lib.ruh.ac.lk filetype:pdf
Yahoo	(link: www.lib.ruh.ac.lk/AND NOT OR		
	(link: www.lib.ruh.ac.lk/AND NOT	(link: www.lib.ruh.ac.lk/AND	site: lib.ruh.ac.lk
	(url: www.lib.ruh.ac.lk/AND link: www.lib.ruh.ac.lk/))	url: www.lib.ruh.ac.lk/))	
Majestic SEO	"External Backlink" parameter from the "FreshIndex"	value of indexed	URL parameter

and Google Scholar can be used to find the number of scholars. The reason to propose the use of two search engines and a software tool was to cross-verify the results because the indexing techniques applied by search engines are different in terms of technology and approach. The specific search keywords assigned by the search engines to retrieve the required information along with search syntax have been presented in the Table 2.

Construct grey decision matrix: A grey decision matrix (D) can be derived following the linguistic terms, x_{ij}, that represents the performance rating of each decision alternative A_i (i = 1, 2,...n) against each criterion C_j (j = 1, 2, 3, 4).

$$D = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_n \end{array} \begin{bmatrix} C_1 & C_2 & C_3 & C_4 \\ G_{11} & G_{12} & G_{13} & G_{14} \\ G_{21} & G_{22} & G_{23} & G_{24} \\ \vdots & \vdots & \ddots & \vdots \\ G_{n1} & G_{n2} & G_{n3} & G_{n4} \end{bmatrix} \quad (7)$$

where, G_{ij} are linguistic variables based on the grey number $\left[\underline{G}, \overline{G}\right]$.

Construct normalized grey decision matrix: The purpose of normalize the above grey decision matrix was to convert each values in the range of 0 and 1. So, a normalized grey decision matrix (D*) was constructed from normalizing each criterion (x_{ij}) in Eq. 7 by using Eq. 9 or Eq. 10 as Eq. 8:

$$D = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_n \end{array} \begin{bmatrix} C_1 & C_2 & C_3 & C_4 \\ G^*_{11} & G^*_{12} & G^*_{13} & G^*_{14} \\ G^*_{21} & G^*_{22} & G^*_{23} & G^*_{24} \\ \vdots & \vdots & \ddots & \vdots \\ G^*_{n1} & G^*_{n2} & G^*_{n3} & G^*_{n4} \end{bmatrix} \quad (8)$$

If the value of criteria (C_i) is greater, the better, then:

$$G^*_{ij} = \left[\frac{\underline{G}_{ij}}{G^{max}_j}, \frac{\overline{G}_{ij}}{G^{max}_j}\right];\ G^{max}_j = \max_{1\le i\le n}\left\{\overline{G}_{ij}\right\} \quad (9)$$

Otherwise:

$$G^*_{ij} = \left[\frac{G^{min}_j}{\overline{G}_{ij}}, \frac{G^{min}_j}{\underline{G}_{ij}}\right];\ G^{min}_j = \min_{1\le i\le n}\left\{\underline{G}_{ij}\right\} \quad (10)$$

Computing the weighted vector of evaluating criteria: The corresponding criteria weights (w_j) in each criterion can be calculated with the application of the normalized grey decision matrix (Eq. 8 as Eq. 11):

$$w_j = \frac{\sum_{p=1}^{n} G^*_{pj}}{\sum_{p=1}^{n}\sum_{q=1}^{4} G^*_{pq}} \quad j = 1, 2, 3, 4 \quad (11)$$

Construct weighted normalized grey decision matrix: The overall performance of each alternative against each criterion will represent from the weighted normalized grey decision matrix and it can be established by multiplying the criteria weights (w_j) with the normalized grey decision matrix $\left(G^*_{ij}\right)$ as Eq. 12:

$$H = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_n \end{array} \begin{bmatrix} C_1 & C_2 & C_3 & C_4 \\ V_{11} & V_{12} & V_{13} & V_{14} \\ V_{21} & V_{22} & V_{23} & V_{24} \\ \vdots & \vdots & \ddots & \vdots \\ V_{n1} & V_{n2} & V_{n3} & V_{n4} \end{bmatrix} \quad (12)$$

where, $V_{ij} = G^*_{ij} \times w_j$.

Computation of the ideal alternative for each grey matrix: The concept of the ideal solution has been widely used to get the most relevant decision results for given decision situation while solving practical decision problems because of its capability to measure the relative performance of the decision alternatives simplicity, comprehensibility and efficiently. The ideal referential alternative (A^{max}) for each criterion can be obtained by Eq. 13:

$$A^{max} = \left\{G^{max}_1, G^{max}_2, G^{max}_3, G^{max}_4\right\} \quad (13)$$

Where:

$$G^{max}_j = \left[\max_{1\le i\le n}\underline{V}_{ij}, \max_{1\le i\le n}\overline{V}_{ij}\right]$$

Calculate the grey possibility degree: The grey possibility degree can be calculated by comparing alternative set ($A = \{A_1, A_2, \ldots\ldots, A_n\}$) with ideal referential alternative $\left\{A^{max} = \left(G_1^{max}, G_2^{max}, G_3^{max}, G_4^{max}\right)\right\}$ as Eq. 14 with Eq. 6:

$$P\left\{A_i \le A^{max}\right\} = \frac{1}{4}\sum_{j=1}^{4} P\left\{V_{ij} \le G_j^{max}\right\} \quad (14)$$

Rank the order of alternatives: The alternative which has a smaller value in $P\{A_i \le A^{max}\}$ can be considered as a best alternative from others. According to the above scenario, the ranking order of all alternatives can be determined with best alternative from among a set of alternatives.

RESULTS

Case application: A case application was conducted to assess the web presence of university library websites in Sri Lanka to illustrate the applicability of the model designed.

Selection of universities: The URLs of these university library websites were identified by visiting the parent university websites and verifying that these URLs were in separate domains for these library website and subject directory indexed. In here, examine 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 3, together with their corresponding URLs.

Calculate the overall performance index: The original data for each criterion were gathered based on search syntax of Table 2 and data were collected on three different occasions. As data was collected on different periods of time, the average value of each criterion is presented in the Table 4.

Herein, it can be seen that the measuring criteria include different range of values. Therefore, any comparisons among those criteria are not logically acceptable. So Table 5 was designed to express the interval grey numbers with regard to each criterion ranges and then the comparisons can simply be made while the grey decision matrix was build-up as described in Eq. 7 and presented in Table 6.

Then the normalized grey decision matrix (Table 7) was calculated according to Eq. 8-10.

According to Eq. 11, the weighted vector of evaluating criteria has obtained and the results are as follows:

Page count = [0.2654,0.2484]
External backlink = [0.2749,0.2614]
Rich files = [0.2322,0.2745]
Scholars = [0.2275,0.2157]

The grey weighted normalized decision matrix was calculated from Eq. 12 as shown in Table 8.

According to Eq. 13, the ideal alternative for each grey matrix U^{max} is shown as follows:

$$U^{max} = \{[0.2275, 0.2484], [0.2356, 0.2614], [0.1548, 0.2745], [0.1950, 0.2157]\}$$

The results of the grey possibility degree in each alternative have obtained from Eq. 14 and the final results of ranking order are shown in Table 9.

According to the results, University of Colombo library website reached to the first place with 0.5872 overall performance index in comparison with the rest of Sri Lankan university library websites. The Open University of Sri Lanka library website comes second and University of Jaffna and University of the Visual & Performing Arts library websites are the last ranked. Furthermore, according to the results generated from the proposed approach, decision makers have a chance to compare with other alternatives according to each criterion also.

Table 3: 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 4: Original data for each library website

Ref#	Page count	External backlink	Rich files	Scholars
U1	262.333	22.000	2	0
U2	3330.000	40.000	3	165
U3	922.000	125.667	2	9
U4	73.667	10.333	1	0
U5	336.000	149.000	1	10
U6	362.000	110.000	2	4
U7	1194.333	59.333	3	5
U8	314.500	111.667	1	1
U9	54.667	1.667	1	0

Table 5: Interval values with regard to each criterion

Scale	Size	Visibility	Rich files	Scholars
Very poor	<= 100	<= 15	<= 0.5	<= 1
Poor	100~300	15~45	0.5~1.5	1~3
Fair	300~500	45~75	1.5~2.5	3~5
Good	500~700	75~105	2.5~3.5	5~7
Very good	>= 700	>= 105	>= 3.5	>= 7

Table 6: Grey decision matrix

Ref#	Page count	External Backlink	Rich Files	Scholars
U1	[1, 3]	[1, 3]	[3, 4]	[0, 1]
U2	[6, 7]	[1, 3]	[4, 6]	[6, 7]
U3	[6, 7]	[6, 7]	[3, 4]	[6, 7]
U4	[0, 1]	[0, 1]	[1, 3]	[0, 1]
U5	[3, 4]	[6, 7]	[1, 3]	[6, 7]
U6	[3, 4]	[6, 7]	[3, 4]	[3, 4]
U7	[6, 7]	[3, 4]	[4, 6]	[3, 4]
U8	[3, 4]	[6, 7]	[1, 3]	[0, 1]
U9	[0, 1]	[0, 1]	[1, 3]	[0, 1]

DISCUSSION

This evaluation indicates the extent to which each website has successfully represented itself on the internet. In general, the successful presence of the websites on the web can be attributed to possessing appropriate number of web pages that influence their visibility through search engines and thereby the number of received external links. In literature relevant to the effectiveness of websites, most studies were analyzed by means of personal knowledge, experience, judgment and statistical software[2,12,20,22,45]. Apart from that, this study aimed to build an understandable and applicable grey model in multi criteria decision making environment and expected that this model may provide an effective and scientific measurement, not only for assessing the web presence, but also for other services as well. The advantages of the degree of grey possibility theory concept that will help to avoid the complex and unreliable process of comparing grey numbers were taken into the custody to retain accuracy with a high degree of consensus while developing the model. Grey tools provide faster and better results and it provides better decision making, flexibility and ability to check inconsistency and was able to handle hierarchies of criteria. The proposed model gains the facility to identify the webometrics level of one's website against those of relatives

Table 7: Normalized grey decision matrix

Ref#	Page count	External Backlink	Rich Files	Scholars
U1	[0.1429, 0.4286]	[0.1429, 0.4286]	[0.5000, 0.6667]	[0.0000, 001429]
U2	[0.8571, 1.0000]	[0.1429, 0.4286]	[0.6667, 1.0000]	[0.8571, 1.0000]
U3	[0.8571, 1.0000]	[0.8571, 1.0000]	[0.5000, 0.6667]	[0.8571, 1.0000]
U4	[0.0000, 0.1429]	[0..0000, 0.1429]	[0.1667, 0.5000]	[0.0000, 0.1429]
U5	[0.4286, 0.5714]	[0.8571, 1.0000]	[0.1667, 0.5000]	[0.8571, 1.0000]
U6	[0.4286, 0.5714]	[0.8571, 1.0000]	[0.5000, 0.6667]	[0.4286, 0.5714]
U7	[0.8571, 1.0000]	[0.4286, 0.5714]	[0.6667, 1.0000]	[0.4286, 0.5714]
U8	[0.4286, 0.5714]	[0.8571, 1.0000]	[0.1667, 0.5000]	[0.0000, 0.1429]
U9	[0.0000, 0.1428]	[0.0000, 0.1429]	[0.1667, 0.5000]	[0.0000, 0.1429]

Table 8: Weighted normalized grey decision matrix

Ref#	Page count	External Backlink	Rich Files	Scholars
U1	[0.0379, 0.1064]	[0.0393, 0.1120]	[0.1161, 0.1830]	[0.0000, 0.0308]
U2	[0.2275, 0.2484]	[0.0393, 0.1120]	[0.1548, 0.2745]	[0.1950, 0.2157]
U3	[0.2275, 0.2484]	[0.2356, 0.2614]	[0.1161, 0.1830]	[0.1950, 0.2157]
U4	[0.0000, 0.0355]	[0.0000, 0.0373]	[0.0387, 0.1373]	[0.0000, 0.0308]
U5	[0.1137, 0.1419]	[0.2356, 0.2614]	[0.0387, 0.1373]	[0.1950, 0.2157]
U6	[0.1137, 0.1419]	[0.2356, 0.2614]	[0.1161, 0.1830]	[0.0978, 0.1232]
U7	[0.2275, 0.2484]	[0.1178, 0.1494]	[0.1548, 0.2745]	[0.0975.0.1232]
U8	[0.1137, 0.1419]	[0.2356, 0.2614]	[0.0387, 0.1373]	[0.0000, 0.0308]
U9	[0.0000, 0.0355]	[0.0000, 0.0373]	[0.0387, 0.1373]	[0.0000, 0.0308]

Table 9: Final results of grey possibility degree

	U1	U2	U3	U4	U5	U6	U7	U8	U9
P ($U_i \leq U^{max}$)	0.9622	0.6250	0.5872	1.0000	0.7500	0.8372	0.7500	0.8750	1.0000
Rank	7	2	1	8	3	5	3	6	8

while web administrators can make strategic and resource allocation assessments to improve the website effectiveness for achieving success.

The findings of this research regarding the performance quality of website corroborate the findings of the study by Li *et al.*[16] which showed that the grey theories proves to be the reliable way for a user to make a decision for choosing a best website that fulfills user satisfaction. Unlike Li *et al.*[16], 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. A study done by Akgul[46] used various dimensions of quality in order to measure websites' 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 grey based 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. The study by Yaokumah *et al.*[47] 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 web presence status of their website. Kaur *et al.*[48] 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. Jati and Dominic[49] 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 grey 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.

The case study shows that the proposed model is applicable as a website effectiveness evaluation technique with quantitative data and may provide an effective and scientific measurement with flexibility and robustness. In particular, it affirms that the model fulfills with the capacity of handling the inherent uncertainty and vagueness of the human decision making process. The case study findings indicate an opportunity for librarians to enhance their webometric ranks by increasing the size of their websites, as enlarging the website size would result in an increased richness as well. Electronic publishing and distributing scientific materials via a library website will attract more audience and as a result the website will receive more external backlinks, leading to higher web presence status[38]. Furthermore, establishing new websites and web logs under the main website and linking them to their affiliate universities, university libraries, international websites, internet guides and search engines can be very effective in enhancing the rate of web links, size and web presence of library websites. Resolving these limitations can promote the visibility of library websites and thereby expansion of the number of users, size, external links, rich files and scholar articles, which in turn would lead to an improved indexing in search engines.

The proposed model renders many advantages, i.e., it uses more understandable scale to compare factors and simple mathematical calculations to determine the important weights, enables to make both quantitative and qualitative assessments, capabilities to work with partially available data set and can be changed the value range of interval grey numbers according to required boundaries. Finally, the outcomes of this study will be to fill a gap of prevailing specific research studies conducted related to the scientific models which numerically evaluate web presence using pair-wise comparison values instead of traditional ways.

CONCLUSION

This paper proposes a multi-level grey evaluation model based on MCDM methodology and real world application to evaluate web presence of websites in an uncertain environment. The proposed model has capabilities to produce effective ranking results with easy computations while the results are continuing as an accurate with a high degree of consensus. The main criteria that affect to the effectiveness of a website and the quantitative data collection strategies were derived from reviewing previous studies as well as discussions with local experts which has shown some potential. Furthermore, the authors were affiliated grey set theories into the model to avoid uncertainty, ambiguity and loss of data and difficulties faced in assessment cycle while the final performance quality index value was generated by applying a grey possibility degree. Finally, the case study shows that the model is applicable as an evaluation technique and may provide an effective and scientific measurement.

The final results will help decision makers to know what improvements are needed to enhance the effectiveness of their websites. The paper proposed to adopt fuzzy and TOPSIS concepts as future studies to evaluate the effectiveness of websites and then the results can be compared with that of those presented in this paper.

SIGNIFICANCE STATEMENTS

The outcomes of this study could redound significantly to the benefit of technological society in the area of web design and its' performance evaluation. In addition, it could also contribute towards indicating the extent to which each website 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 research to knowledge are at least:

- An identification of generic criteria to affect to the web presence
- An explanation of how these generic criteria can be applied to web design
- A grey based framework of how these criteria can be used to benchmark and evaluate web presence of 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
- The proposed approach is cost effective in comparison to traditional evaluation methods

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