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Selection and ranking of E-learning websites using weighted distance-based approximation

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Abstract The propagation of the web applications as E-learning websites has produced new opportunities as well as new challenges for academic organizations and individuals who are either delivering or receiving an education. The E-learning websites has become more and more popular from the last few decades due to the great benefits provided by the concept of E-learning such as study at any time and any place. Now a day, a number of organizations have developed their website to deliver the skills and the knowledge in the field of education. The rapid increase in the use of E-learning leads to the problem of E-learning evaluation and selection. The evaluation of E-learning websites might be considered from the perspective of multi-criteria decision making (MCDM) problems. In this research, the problem of the E-learning websites evaluation and selection is modeled as a MCDM problem. Further, for the evaluation and selection of E-learning websites, weighted distance-based approximation (WDBA) method is proposed that has a number of significant advantages over the existing ones. To validate the proposed methodology, WDBA, a comparison with the existing methodology, namely technique for order preference by similarity to ideal solution is also provided.

Keywords Multi-criteria decision making (MCDM) · Selection criteria · E-learning websites · WDBA

Introduction

The developments in the information technology have the significant effect on the educational sector. To enhance the teaching and learning process, a new technology named as E-learning was invented by the web developers to provide

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the education effectively. E-learning is an emerging area of education that is growing exponentially and one that provides an effective, efficient, and modern way of learning. E-learning is referred as a process in which knowledge is acquired by the means of electronic media such as internet, video/audio tape, and intranets. (Syamsuddin 2012; Anohina 2005; Lee-Post 2009). Abdellatief et al. (2011) represent the E-learning as a process that incorporate educational activities carried out by the individuals or groups via networked computers and electronic devices. E-learning in the higher education provides the facility to the students to learn anytime and anywhere without attending any academic organizations (Prougestaporn et al. 2015; Lanzilotti et al. 2006). E-learning is also referred as the distance learning because the student has the freedom to learn outside the classroom (Shee and Wang 2008).

In the recent years, the use of the E-learning system has increased rapidly due to the significant advantages as saved cost, better quality, less delivery time, etc. (Mohamed et al. 2015). According to Cristina (2012), E-learning systems are organized into three fundamental components as learning management system (LMS), learning content management system (LMCS), and a set of tools. The LMS integrates all the aspects for supervision of online teaching activities, and LCMS provides services for managing the contents of the website and the tools represent services for managing teaching processes and interactions among the various users as teachers, students, and administrators. As the popularity of E-learning websites is increasing, there is a need to develop a procedure that can evaluate the various E-learning websites for their selection purpose (Baruque et al. 2007).

This paper argues that the problem of the evaluation and selection of E-learning websites can be modeled as multi-criteria decision making problem (MCDM), and there is need to develop a framework that is capable to solve this MCDM problem in an efficient manner by accommodating the evaluation criteria weights also. The existing approaches in the literature as an analytical hierarchy process (AHP) and technique for order preference by similarity to the ideal solution (TOPSIS) have some limitations as no elicitation of weights, more complexity, etc. In this paper, a novel approach for the E-learning websites evaluation and selection is developed using weighted distance-based approximation (WDBA) approach. The proper evaluation and selection of E-learning websites will result into the great benefits to all the users of website as teachers, students, and administrators.

The rest of the paper is organized as A literature review about the E-learning websites evaluation and selection in "Literature review" section, the proposed methodology is described in "Proposed methodology" section. To demonstrate the applicability of the proposed methodology, an empirical study is presented in "An empirical example" section. The methodology validation is given in "Methodology validation" section followed by results in "Results" section and conclusions and future scope in "Conclusions and future scope" section of the paper.

Literature review

A lot of research has been carried out by the various researchers to solve the problem of evaluation and selection of E-learning websites. Covella and Olsina Santos (2002) present the use of quality evaluation methodology, namely WebQEM by considering functional characteristics consisting of usability, reliability, efficiency, student features, virtual learning environment features, course features, etc., as the evaluation criteria in this work. The WebQEM methodology proposed in this research is capable to find the degree of fulfillment of the quality requirements of any E-learning website. In the contemporary work, the quality factors such as scalability, performance, cost/benefit, portability, robustness, correctness, usability, and reliability were considered as the evaluation criteria for the evaluation and selection of E-learning websites by Khaddaj and Horgan (2004).

Zhang and Nunamaker (2004) proposed an approach for the evaluation and selection of E-learning websites based on the multimedia concept such as video clips. Pruengkarn et al. (2005) addressed the problem of evaluation and selection of E-learning websites by considering quality factors such as functionality, maintainability, portability, usability, reliability, and efficiency as the selection criteria.

Lanzilotti et al. (2006) develop a framework named as TICS for the quality evaluation of E-learning websites where as Büyüközkan et al. (2007) modeled the problem of the evaluation and selection of E-learning websites as MCDM problem and provide a comprehensive list of seven evaluation criteria as right and understandable content, complete content, personalization, security, navigation, interactivity, and user interface. In the similar way, Shee and Wang (2008) proposed a web-based E-learning system WELS for the evaluation of E-learning website. Goi and Ng (2009) considered program content, web page accessibility, learners' participation and involvement, web site security and support, institutional commitment, interactive learning environment, instructor competency, and presentation and design as the selection criteria for the evaluation and selection of E-learning websites, whereas Plantak Vukovac et al. (2010) present the usability as the evaluation criteria for the evaluation and selection of E-learning websites.

Liu et al. (2011) presents a multi-dimensional set of evaluation criteria to evaluate the quality of E-leaning websites related to the English learning based on the usability, technology integration, learner preferences, learning materials, etc. Mehregan et al. (2011) proposed an approach for the evaluation and selection of E-learning websites based on fuzzy analytic hierarchy process (FAHP). Abdellatief et al. (2011) proposed the quality characteristic for the evaluation of E-learning websites. In the contemporary work, Syamsuddin (2012) develop a framework by combining AHP with fuzzy set theory. Lui et al. (2013) proposed a framework to evaluate the mathematical E-learning platforms by considering functions, learning activity, infrastructure, specialization, learning experience, customization, and learning context as the evaluation criteria. Prougestaporn et al. (2015) present cost, speed, efficiency, and quality as the selection criteria for evaluation and selection of E-learning websites.

Proposed methodology

In this research, WDBA method is adopted for the evaluation, selection, and ranking of E-learning websites which is already applied to the evaluation and selection of COTS components in (Garg et al. 2016). The proposed methodology WDBA is based on various simple matrix operations. In this approach, the alternatives are evaluated against an identified set of evaluation criteria and ranked according to the computed composite distance/suitability index. The alternative to having the lowest value for the suitability index is ranked at number #1 and the alternative with the highest value is ranked at last. The various steps of the proposed methodology are summarized below.

Step 1: Construct the criteria rating matrix (R_{ij}):

$$R_{ij} = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1m} \\ r_{21} & r_{22} & \cdots & r_{2m} \\ \vdots & \vdots & \vdots & \vdots \\ r_{n1} & r_{n2} & \cdots & r_{nm} \\ c_1 & c_2 & \cdots & c_n \end{bmatrix}, \quad (1)$$

where r_{ij} ($i = 1, \ldots\ldots, m, j = 1, \ldots.., n$) represents the performance rating of ith alternative with respect to jth criteria and c_j ($j = 1, \ldots\ldots, n$) represents the weight of the jth criteria.

Step 2: Formulate the weighted criteria rating matrix (W_{ij}) by multiplying each performance rating by its associated weights of the criteria.

$$W_{ij} = \begin{bmatrix} w_{11} & w_{12} & \cdots & w_{1m} \\ w_{21} & w_{22} & \cdots & w_{2m} \\ \vdots & \vdots & \vdots & \vdots \\ w_{n1} & w_{n2} & \cdots & w_{nm} \end{bmatrix}. \quad (2)$$

Step 3: Formulate the adjusted matrix (A_{ij}) by subtracting the optimal values from the weighted criteria rating matrix. Now, the standardized matrix (S_{ij}) is formulated as

$$s_{ij} = \begin{bmatrix} s_{11} & s_{12} & \cdots & s1_{m} \\ s21 & s_{22} & \cdots & s_{2m} \\ \vdots & \vdots & \vdots & \vdots \\ s_{n1} & s_{n2} & \cdots & s_{nm} \\ s_{o1} & s_{o2} & \cdots & s_{om} \end{bmatrix}, \quad (3)$$

$$S_{ij} = \frac{A_{ij} - \overline{p}_j}{\mathrm{SD}_j}, \quad \overline{p}_j = \frac{1}{n}\sum_{i=1}^{n} A_{ij}, \quad \mathrm{SD}_j = \left[\frac{1}{n}\sum_{i=1}^{n} (A_{ij} - \overline{p}_j)^2\right]^{1/2}$$

where n—number of criteria, $\overline{p}_j$—average value, SD_j—standard deviation.

Step 4: Distance matrix (D_{ij}) can be formulated as

$$D_{ij} = \begin{bmatrix} s_{o1} - s_{11} & s_{o2} - s_{12} & \cdots & s_{om} - s_{1m} \\ s_{o1} - s_{21} & s_{o2} - s_{22} & \cdots & s_{om} - s_{2m} \\ \vdots & \vdots & \vdots & \vdots \\ s_{o1} - s_{n1} & s_{o2} - s_{n2} & \cdots & s_{om} - s_{nm} \end{bmatrix}. \tag{4}$$

Step 5: Formulate the composite distance matrix (CD_{ij}) by taking the square of the above distance matrix (D_{ij}). Finally, calculate the composite distance/suitability index (SI) as given below.

$$\mathrm{SI} = \sqrt{\sum_{j=1}^{m} (\mathrm{CD}_{ij})}. \tag{5}$$

An empirical example

To show the applicability of the proposed methodology, a dataset including twenty one E-learning websites by considering seven evaluation criteria as provided in (Büyüközkan et al. 2007). These twenty one E-learning websites are the most popular educational websites and commonly used by the students in Turkish. Further, the weights of the evaluation criteria were determined by implementing fuzzy set theory (FST) on the collected data from the experts by means of a questionnaire (Büyüközkan et al. 2007). All the seven evaluation criteria have their own significance in the evaluation process. The description of these twenty one E-learning websites and the seven evaluation criteria is provided in Tables 1 and 2, respectively.

Table 1 Description of twenty one E-learning websites

Label	Web address	Label	Web address
W1	www.online-degree-enlightenment.com	W12	http://www.kidsplus.com.tr
W2	www.youachieve.com	W13	http://www.medyasoft.com.tr
W3	www.elearninginstitute.ca	W14	http://www.ideaelearning.com
W4	www.online-education-resources.com	W15	http://www.sanal-kampus.com
W5	www.good-tutorials.com	W16	http://www.netron.com.tr
W6	www.courses.telecampus.edua	W17	http://www.kocbryce.com.tr
W7	www.universalclass.com	W18	http://www.enocta.com
W8	www.sp.edu.sg	W19	http://www.buelc.boun.edu.tr
W9	www.ocw.mit.edu	W20	http://www.aof.anadolu.edu.tr
W10	www.geolearning.com	W21	http://euniversite.orga
W11	http://businessacademy.sbs.com.tr		

Table 2 Description of evaluation criteria

Criteria name	Definition
Right and understandable content (C1)	The purpose of this criterion is that the contents should be well understood, unambiguous, and succinct
Complete content (C2)	This criterion includes the coverage and accuracy. The purpose of this criterion is that the content is correct, up-to-date, factual, exact, and detailed
Personalization (C3)	Personalization is a means of meeting the customer requirements in an effective and efficient manner
Security (C4)	Security is a major issue in the websites. To place the information secretly in the websites, a digital certificate is desirable for this purpose
Navigation (C5)	Navigation measures how easy it is to navigate around the site, how it is easy to find the relevant information
Interactivity (C6)	Interactivity deals between the learners and the E-learning tools through which the level of interaction of learners involved in the learning process
User interface (C7)	This criterion includes the consistency, information structure, design, appearance, and organization of the websites. The organization of the websites should be well understood by the e-learners

The performance ratings of E-learning websites and relative importance/weights of the evaluation criteria used in this study are provided in Tables 3 and 4, respectively.

Table 3 Evaluation criteria weights

Criteria no.	Criteria name	Criteria weights
C1	Right and understandable content	0.73
C2	Complete content	0.90
C3	Personalization	0.10
C4	Security	0.26
C5	Navigation	0.10
C6	Interactivity	0.26
C7	User interface	0.50

Table 4 Performance ratings of E-learning websites

Alternative/criteria	C1	C2	C3	C4	C5	C6	C7
W1	0.71	0.85	0.12	0.14	0.29	0.38	0.36
W2	0.88	0.88	0.50	0.71	0.84	0.85	0.88
W3	0.89	0.84	0.38	0.71	0.89	0.88	0.68
W4	0.80	0.89	0.59	0.89	0.88	0.88	0.68
W5	0.71	0.88	0.88	0.80	0.71	0.71	0.71
W6	0.41	0.20	0.20	0.68	0.29	0.32	0.29
W7	0.38	0.29	0.88	0.68	0.61	0.50	0.59
W8	0.88	0.88	0.50	0.71	0.56	0.59	0.71
W9	0.88	0.89	0.68	0.89	0.89	0.89	0.89

Table 4 continued

Alternative/criteria	C1	C2	C3	C4	C5	C6	C7
W10	0.84	0.20	0.20	0.50	0.20	0.32	0.71
W11	0.50	0.29	0.10	0.71	0.88	0.14	0.71
W12	0.88	0.68	0.29	0.71	0.88	0.32	0.71
W13	0.84	0.20	0.59	0.41	0.71	0.29	0.71
W14	0.29	0.71	0.68	0.20	0.71	0.68	0.50
W15	0.71	0.85	0.80	0.89	0.71	0.29	0.71
W16	0.41	0.50	0.41	0.71	0.20	0.29	0.29
W17	0.84	0.68	0.68	0.89	0.89	0.32	0.14
W18	0.88	0.89	0.89	0.89	0.88	0.89	0.85
W19	0.41	0.20	0.80	0.71	0.68	0.59	0.50
W20	0.89	0.89	0.68	0.89	0.89	0.38	0.89
W21	0.59	0.68	0.20	0.62	0.29	0.50	0.71

The criteria rating matrix can be formed by using Eq. (1) as

$$R_{ij} = \begin{bmatrix} 0.71 & 0.85 & 0.12 & 0.14 & 0.29 & 0.38 & 0.36 \\ 0.88 & 0.88 & 0.50 & 0.71 & 0.84 & 0.85 & 0.88 \\ 0.89 & 0.84 & 0.38 & 0.71 & 0.89 & 0.88 & 0.68 \\ 0.80 & 0.89 & 0.59 & 0.89 & 0.88 & 0.88 & 0.68 \\ 0.71 & 0.88 & 0.88 & 0.80 & 0.71 & 0.71 & 0.71 \\ 0.41 & 0.20 & 0.20 & 0.68 & 0.29 & 0.32 & 0.29 \\ 0.38 & 0.29 & 0.88 & 0.68 & 0.61 & 0.50 & 0.59 \\ 0.88 & 0.88 & 0.50 & 0.71 & 0.56 & 0.59 & 0.71 \\ 0.88 & 0.89 & 0.68 & 0.89 & 0.89 & 0.89 & 0.89 \\ 0.84 & 0.20 & 0.20 & 0.50 & 0.20 & 0.32 & 0.71 \\ 0.50 & 0.29 & 0.10 & 0.71 & 0.88 & 0.14 & 0.71 \\ 0.88 & 0.68 & 0.29 & 0.71 & 0.88 & 0.32 & 0.71 \\ 0.84 & 0.20 & 0.59 & 0.41 & 0.71 & 0.29 & 0.71 \\ 0.29 & 0.71 & 0.68 & 0.20 & 0.71 & 0.68 & 0.50 \\ 0.71 & 0.85 & 0.80 & 0.89 & 0.71 & 0.29 & 0.71 \\ 0.41 & 0.50 & 0.41 & 0.71 & 0.20 & 0.29 & 0.29 \\ 0.84 & 0.68 & 0.68 & 0.89 & 0.89 & 0.32 & 0.14 \\ 0.88 & 0.89 & 0.89 & 0.89 & 0.88 & 0.89 & 0.85 \\ 0.41 & 0.20 & 0.80 & 0.71 & 0.68 & 0.59 & 0.50 \\ 0.89 & 0.89 & 0.68 & 0.89 & 0.89 & 0.38 & 0.89 \\ 0.59 & 0.68 & 0.20 & 0.62 & 0.29 & 0.50 & 0.71 \\ 0.73 & 0.90 & 0.10 & 0.26 & 0.10 & 0.26 & 0.50 \end{bmatrix}.$$

The weighted criteria rating matrix can be formed by using Eq. (2) as

$$W_{ij} = \begin{bmatrix} 0.5183 & 0.7650 & 0.0120 & 0.0364 & 0.0290 & 0.0988 & 0.1800 \\ 0.6424 & 0.7920 & 0.0500 & 0.1846 & 0.0840 & 0.2210 & 0.4400 \\ 0.6497 & 0.7560 & 0.0380 & 0.1846 & 0.0890 & 0.2288 & 0.3400 \\ 0.5840 & 0.8010 & 0.0590 & 0.2314 & 0.0880 & 0.2288 & 0.3400 \\ 0.5183 & 0.7920 & 0.0880 & 0.2080 & 0.0710 & 0.1846 & 0.3550 \\ 0.2993 & 0.1800 & 0.0200 & 0.1768 & 0.0290 & 0.0832 & 0.1450 \\ 0.2774 & 0.2610 & 0.0880 & 0.1768 & 0.0610 & 0.1300 & 0.2950 \\ 0.6424 & 0.7920 & 0.0500 & 0.1846 & 0.0560 & 0.1534 & 0.3550 \\ 0.6424 & 0.8010 & 0.0680 & 0.2314 & 0.0890 & 0.2314 & 0.4450 \\ 0.6132 & 0.1800 & 0.0200 & 0.1300 & 0.0200 & 0.0832 & 0.3550 \\ 0.3650 & 0.2610 & 0.0100 & 0.1846 & 0.0880 & 0.0364 & 0.3550 \\ 0.6424 & 0.6120 & 0.0290 & 0.1846 & 0.0880 & 0.0832 & 0.3550 \\ 0.6132 & 0.1800 & 0.0590 & 0.1066 & 0.0710 & 0.0754 & 0.3550 \\ 0.2117 & 0.6390 & 0.0680 & 0.0520 & 0.0710 & 0.1768 & 0.2500 \\ 0.5183 & 0.7650 & 0.0800 & 0.2314 & 0.0710 & 0.0754 & 0.3550 \\ 0.2993 & 0.4500 & 0.0410 & 0.1846 & 0.0200 & 0.0754 & 0.1450 \\ 0.6132 & 0.6120 & 0.0680 & 0.2314 & 0.0890 & 0.0832 & 0.0700 \\ 0.6424 & 0.8010 & 0.0890 & 0.2314 & 0.0880 & 0.2314 & 0.4250 \\ 0.2993 & 0.1800 & 0.0800 & 0.1846 & 0.0680 & 0.1534 & 0.2500 \\ 0.6497 & 0.8010 & 0.0680 & 0.2314 & 0.0890 & 0.0988 & 0.4450 \\ 0.4307 & 0.6120 & 0.0200 & 0.1612 & 0.0290 & 0.1300 & 0.3550 \end{bmatrix}.$$

Now, average and standard deviation are obtained as 0.2965, 0.3930, 0.0426, 0.1411, 0.0461, 0.0999, 0.2448, 0.1529, 0.2545, 0.0264, 0.0556, 0.0254, 0.0641, and 0.1050 respectively. The standardized matrix can be written by using Eq. (3) as

$$S_{ij} = \begin{bmatrix} 0.06591 & 0.75437 & -1.53895 & -2.53657 & -1.45815 & -0.58513 & -1.28352 \\ 0.87733 & 0.86046 & -0.09923 & 0.12683 & 0.70381 & 1.32088 & 1.19281 \\ 0.92506 & 0.71901 & -0.55388 & 0.12683 & 0.90035 & 1.44254 & 0.24038 \\ 0.49549 & 0.89582 & 0.24176 & 0.96790 & 0.86104 & 1.44254 & 0.24038 \\ 0.06591 & 0.86046 & 1.34049 & 0.54736 & 0.19280 & 0.75314 & 0.38324 \\ -1.36599 & -1.54411 & -1.23585 & -0.01335 & -1.45815 & -0.82845 & -1.61688 \\ -1.50918 & -1.22586 & 1.34049 & -0.01335 & -0.20028 & -0.09849 & -0.18822 \\ 0.87733 & 0.86046 & -0.09923 & 0.12683 & -0.39683 & 0.26649 & 0.38324 \\ 0.87733 & 0.89582 & 0.58274 & 0.96790 & 0.90035 & 1.48310 & 1.24044 \\ 0.68641 & -1.54411 & -1.23585 & -0.85442 & -1.81192 & -0.82845 & 0.38324 \\ -0.93642 & -1.22586 & -1.61472 & 0.12683 & 0.86104 & -1.55841 & 0.38324 \\ 0.87733 & 0.15323 & -0.89486 & 0.12683 & 0.86104 & -0.82845 & 0.38324 \\ 0.68641 & -1.54411 & 0.24176 & -1.27496 & 0.19280 & -0.95011 & 0.38324 \\ -1.93876 & 0.25932 & 0.58274 & -2.25621 & 0.19280 & 0.63148 & -0.61682 \\ 0.06591 & 0.75437 & 1.03739 & 0.96790 & 0.19280 & -0.95011 & 0.38324 \\ -1.36599 & -0.48327 & -0.44021 & 0.12683 & -1.81192 & -0.95011 & -1.61688 \\ 0.68641 & 0.15323 & 0.58274 & 0.96790 & 0.90035 & -0.82845 & -2.33120 \\ 0.87733 & 0.89582 & 1.37838 & 0.96790 & 0.86104 & 1.48310 & 1.04995 \\ -1.36599 & -1.54411 & 1.03739 & 0.12683 & 0.07487 & 0.26649 & -0.61682 \\ 0.92506 & 0.89582 & 0.58274 & 0.96790 & 0.90035 & -0.58513 & 1.24044 \\ -0.50685 & 0.15323 & -1.23585 & -0.29371 & -1.45815 & -0.09849 & 0.38324 \\ 0.92506 & 0.89582 & 1.37838 & 0.96790 & 0.90035 & 1.48310 & 1.24044 \end{bmatrix}.$$

The composite distance matrix can be formulated as

$$\mathrm{CD}_{ij} = \begin{bmatrix} 0.73813 & 0.02001 & 8.51076 & 12.28128 & 5.56250 & 4.27756 & 6.37037 \\ 0.00228 & 0.00125 & 2.18331 & 0.70740 & 0.03863 & 0.02631 & 0.00227 \\ 0.00000 & 0.03126 & 3.73359 & 0.70740 & 0.00000 & 0.00164 & 1.00012 \\ 0.18453 & 0.00000 & 1.29190 & 0.00000 & 0.00155 & 0.00164 & 1.00012 \\ 0.73813 & 0.00125 & 0.00144 & 0.17685 & 0.50063 & 0.53284 & 0.73478 \\ 5.24892 & 5.95323 & 6.83416 & 0.96285 & 5.56250 & 5.34325 & 8.16424 \\ 5.92554 & 4.50150 & 0.00144 & 0.96285 & 1.21139 & 2.50141 & 2.04106 \\ 0.00228 & 0.00125 & 2.18331 & 0.70740 & 1.68266 & 1.48012 & 0.73478 \\ 0.00228 & 0.00000 & 0.63303 & 0.00000 & 0.00000 & 0.00000 & 0.00000 \\ 0.05695 & 5.95323 & 6.83416 & 3.32086 & 7.35641 & 5.34325 & 0.73478 \\ 3.46511 & 4.50150 & 8.95862 & 0.70740 & 0.00155 & 9.25078 & 0.73478 \\ 0.00228 & 0.55143 & 5.16761 & 0.70740 & 0.00155 & 5.34325 & 0.73478 \\ 0.05695 & 5.95323 & 1.29190 & 5.03041 & 0.50063 & 5.92050 & 0.73478 \\ 8.20143 & 0.40514 & 0.63303 & 10.39487 & 0.50063 & 0.72526 & 3.44939 \\ 0.73813 & 0.02001 & 0.11627 & 0.00000 & 0.50063 & 5.92050 & 0.73478 \\ 5.24892 & 1.90188 & 3.30727 & 0.70740 & 7.35641 & 5.92050 & 8.16424 \\ 0.05695 & 0.55143 & 0.63303 & 0.00000 & 0.00000 & 5.34325 & 12.75662 \\ 0.00228 & 0.00000 & 0.00000 & 0.00000 & 0.00155 & 0.00000 & 0.03629 \\ 5.24892 & 5.95323 & 0.11627 & 0.70740 & 0.68141 & 1.48012 & 3.44939 \\ 0.00000 & 0.00000 & 0.63303 & 0.00000 & 0.00000 & 4.27756 & 0.00000 \\ 2.05036 & 0.55143 & 6.83416 & 1.59165 & 5.56250 & 2.50141 & 0.73478 \end{bmatrix}.$$

Finally, the value of composite distance (CD)/suitability index (SI) is obtained using Eq. (5), and the final ranking of based on the suitability index of twenty one E-learning websites is shown in Table 5 and Fig. 1.

Table 5 Ranking of E-learning websites using WDBA method

E-learning websites	SI	Rank	E-learning websites	SI	Rank	E-learning websites	SI	Rank
W1	6.14497	20	W8	2.60611	8	W15	2.83378	9
W2	1.72089	5	W9	0.79706	2	W16	5.71022	19
W3	2.33966	7	W10	5.44056	18	W17	4.39787	13
W4	1.57472	3	W11	5.25545	17	W18	0.20027	1
W5	1.63888	4	W12	3.53671	10	W19	4.19961	12
W6	6.17002	21	W13	4.41457	14	W20	2.21599	6
W7	4.14067	11	W14	4.93049	16	W21	4.45267	15

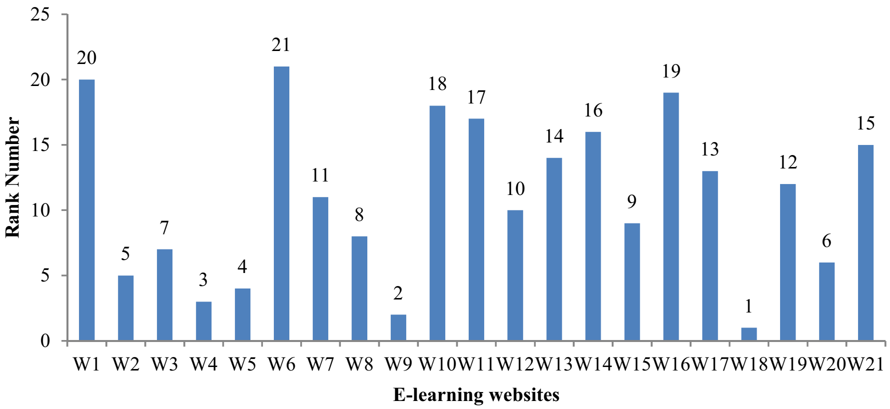

Fig. 1 Ranking of E-learning websites using WDBA method

Methodology validation

In order to validate the methodology and the results obtained, the present E-learning evaluation and selection problem using the same datasets is solved using TOPSIS. TOPSIS is a goal-based approach to solve the multi-criteria decision making problems introduced by Hwang and Yoon (1981). In this approach, a procedure was developed to find the best alternative from a set of alternatives by measuring distance to the ideal solution. The ideal solution comprises a positive ideal solution and a negative ideal solution. The ranking results of the E-learning websites namely (W1-W21) based on seven criteria (Right and understandable content, Complete content, Personalization, Security, Navigation, Interactivity and User interface) using TOPSIS along-with ranking values and difference in rankings are given in Table 6.

The results of rankings obtained using TOPSIS method are different to some extent from the proposed methodology WDBA. The proposed methodology may also be compared with graph theory proposed by Garg et al. (2007) and matrix/fuzzy matrix methods, Garg et al. (2010, 2013). The computations become larger and more time consuming with an increase in the number of criteria hence not suitable for use. However, there arises a need to establish if there is a statistically significant correlation between the preference rankings obtained by these two methods. To test whether such relationship exists or not, Spearman's rank correlation technique is used. Further, two hypotheses are formulated and tested for a significance of α ($\alpha = 0.05$) and a critical 'Z' value, Z_α ($Z_{0.05} = 1.645$). The hypotheses are

H0 There is no positive relationship between $\{x^i\}$ and $\{y^i\}$.

H1 There is a positive relationship between $\{x^i\}$ and $\{y^i\}$.

The test statistics for the ranking pairs of two sets are provided in Table 7.

The value obtained for the rank correlation is 0.8233. The corresponding test statistics is $Z = 3.6819$, which exceeds the critical value of 1.645. Thus, we affirm that the WDBA rankings are strongly positively correlated with other method i.e., TOPSIS.

Table 6 Comparison of ranking obtained from WDBA and TOPSIS

Alternatives	TOPSIS (A)		WDBA (B)		Ranking differences (D = B − A)
	SI	Rank	SI	Rank	
W1	0.606	12	6.14497	20	8
W2	0.846	3	1.72089	5	2
W3	0.795	6	2.33966	7	1
W4	0.813	4	1.57472	3	−1
W5	0.793	7	1.63888	4	−3
W6	0.195	20	6.17002	21	1
W7	0.336	19	4.14067	11	−8
W8	0.797	5	2.60611	8	3
W9	0.871	2	0.79706	2	0
W10	0.440	15	5.44056	18	3
W11	0.370	17	5.25545	17	0
W12	0.670	10	3.53671	10	0
W13	0.424	16	4.41457	14	−2
W14	0.485	14	4.93049	16	2
W15	0.730	9	2.83378	9	0
W16	0.359	18	5.71022	19	1
W17	0.553	13	4.39787	13	0
W18	0.890	1	0.20027	1	0
W19	0.131	21	4.19961	12	−9
W20	0.791	8	2.21599	6	−2
W21	0.649	11	4.45267	15	4

Table 7 Spearman's rank—correlation coefficient and test value

Set of ranking methods	(A–B)
Squared sum ($\sum d^2$)	272
Spearman's rank—correlation coefficient (r_s)	0.8233
Test value (Z)	3.6819

Results

According to the methodology adopted in the present empirical study, the lower the value of composite distance/suitability index implies the better ranking. It means the alternative having the lowest suitability index among all alternatives will be ranked at number #1, whereas the alternative with highest suitability index will be ranked at last. The comparative rankings of all twenty one E-learning websites based on seven evaluation criteria (Right and understandable content, Complete content, Personalization, Security, Navigation, Interactivity and User interface) are provide in

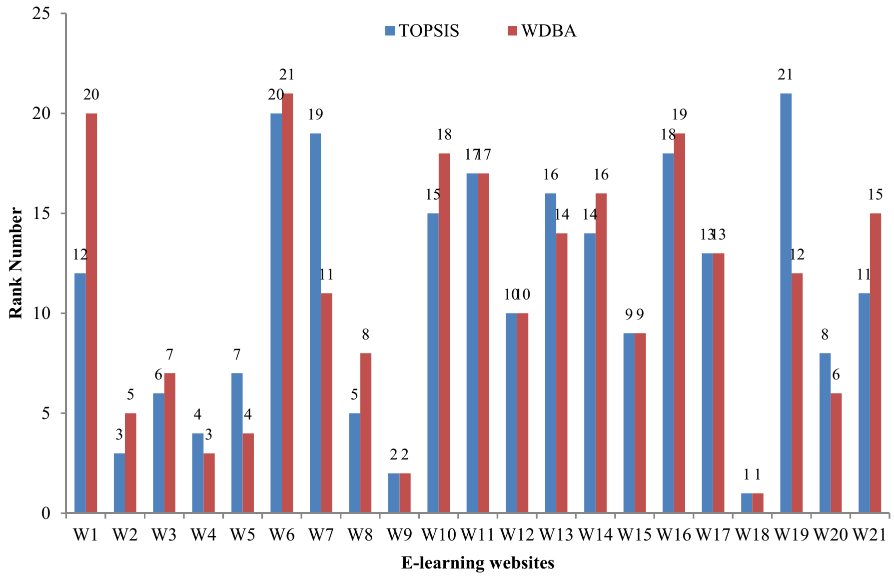

Fig. 2 Comparative ranking obtained from TOPSIS and WDBA method

Table 5 and Fig. 1 that depict that the E-learning website W18 (http://www.enocta.com) having the lowest value of suitability index as 0.20027 is ranked at number #1 followed by W9 (www.ocw.mit.edu) at number #2 and W4 (www.online-education-resources.com) at number #3. The E-learning website labeled as W6 (www.courses.telecampus.edua) is ranked at number #21 i.e., last having the highest value of suitability index. The results obtained in this empirical study depict that the E-learning website W18 is most preferable educational website in Turkish, whereas W6 is least preferable. However, the rankings of E-learning websites abbreviated as W1, W7, and W19 obtained from WDBA and TOPSIS have significant difference. So, it can be concluded that if these three websites are removed from the set of E-learning websites, that is to be evaluated, the proposed methodology WDBA will produce better results in less time as compare to TOPSIS. The comparison of the proposed methodology with the TOPSIS method, as given in Fig. 2, validates the applicability of the proposed methodology as there exists no significant difference in the rankings of the websites with the two methods. The WDBA involves simple mathematical formulations and easy to understand hence is much better that TOPSIS.

Conclusions and future scope

The present research argues the upcoming issue of the evaluation and selection of E-learning websites related to the educational sector. The problem of evaluation and selection of E-learning websites is represented as a multi-criteria decision making problem and novel rationalized approach, namely WDBA is applied to solve the present problem. The proposed WDBA is comparatively more effective and efficient as it involves simple and straightforward mathematical operations such as matrix operations. The relative importance/weights of the identified evaluation criteria are accommodated in the proposed methodology which is previously not applicable in most of the existing methods. To achieve the relative importance/weights of the evaluation criterion, no pairwise comparison is needed that decreases the complexity of the methodology. For example, as in the empirical study, seven evaluation criteria are used then (7×7) i.e., 49 comparisons are required to get the relative importance of the evaluation criteria. The proposed methodology WDBA has a number of limitations such as (1) if the number of evaluation criteria increases, a hierarchical model for the classification of evaluation criteria into various groups must be developed and (2) when evaluation criteria are too much, then the data collection for the E-learning websites against each criteria will increase which in turn will result in high complexity. Further, the proposed methodology is also validated by comparing the results with the existing methodology TOPSIS that depicts that WDBA is more efficient to solve the problem of evaluation and selection of E-learning websites. The proposed research can be enhanced further by applying the elimination search on the evaluation criteria and the E-learning websites so that the calculations will be very easy.

References

Abdellatief, M., Sultan, A. B. M., Jabar, M. A., & Abdullah, R. (2011). A technique for quality evaluation of E-learning from developers perspective. *American Journal of Economics and Business Administration, 3*(1), 157.

Anohina, A. (2005). Analysis of the terminology used in the field of virtual learning. *Journal of Educational Technology & Society, 8*(3), 91–102.

Baruque, L. B., Baruque, C. B., & Melo, R. N. (2007). Towards a framework for corporate E-learning evaluation. In *Proceedings of the 2007 Euro American conference on telematics and information systems* (p. 58). ACM.

Büyüközkan, G., Ruan, D., & Feyzioğlu, O. (2007). Evaluating E-learning web site quality in a fuzzy environment. *International Journal of Intelligent Systems, 22*(5), 567–586.

Covella, G. J., & Olsina Santos, L. A. (2002). Specifying quality characteristics and attributes for E-learning sites. In *IV Workshop de Investigadores en Ciencias de la Computación*.

Cristina, P. O. P. (2012). Evaluation of E-learning platforms: A case study. *Informatica Economica, 16*(1), 155–167.

Garg, R. K., Gupta, V. K., & Agrawal, V. P. (2007). Quality evaluation of a thermal power plant by graph-theoretical methodology. *International Journal of Power and Energy Systems, 27*(1), 42.

Garg, R., Sharma, K., Kumar, R., & Garg, R. K. (2010). Performance analysis of software reliability models using matrix method. *World Academy of Science, Engineering and Technology, 71*, 31–38.

Garg, R. K., Sharma, K., Nagpal, C. K., Garg, R., Garg, R., & Kumar, R. (2013). Ranking of software engineering metrics by fuzzy-based matrix methodology. *Software Testing, Verification and Reliability, 23*(2), 149–168.

Garg, R., Sharma, R., & Sharma, K. (2016). Ranking and selection of commercial off-the-shelf using fuzzy distance based approach. *Decision Science Letters, 5*(2), 201–210.

Goi, C. L., & Ng, P. Y. (2009). E-learning in Malaysia: Success factors in implementing E-learning program. *International Journal of Teaching and Learning in Higher Education, 20*(2), 237–246.

Hwang, C. L., & Yoon, K. (1981). Lecture notes in economics and mathematical systems. In *Multiple Objective Decision Making, Methods and Applications: A State-of-the-Art Survey* (vol. 164). Berlin: Springer.

Khaddaj, S., & Horgan, G. (2004). The evaluation of software quality factors in very large information systems. *Electronic Journal of Information Systems Evaluation, 7*(1), 43–48.

Lanzilotti, R., Ardito, C., Costabile, M. F., & De Angeli, A. (2006). eLSE methodology: A systematic approach to the E-learning systems evaluation. *Journal of Educational Technology & Society, 9*(4), 42–53.

Lee-Post, A. (2009). E-learning success model: An information systems perspective. *Electronic Journal of E-learning, 7*(1), 61–70.

Liu, G. Z., Liu, Z. H., & Hwang, G. J. (2011). Developing multi-dimensional evaluation criteria for English learning websites with university students and professors. *Computers & Education, 56*(1), 65–79.

Lui, R. W., Lo, K. K., & Yiu, S. M. (2013). Evaluating and adopting E-learning platforms. *International Journal of e-Education, e-Business, e-Management and e-Learning, 3*(3), 229.

Mehregan, M. R., Jamporazmey, M., Hosseinzadeh, M., & Mehrafrouz, M. (2011). Proposing an approach for evaluating E-learning by integrating critical success factor and fuzzy AHP. In *International conference on innovation, management and service, Singapore*.

Mohamed, A. M., Fattah, M. A. A., & Gaber, S. A. E. (2015). Constructing multi-dimensional criteria model for evaluating E-learning systems efficiency in the higher educational. *International Journal of Advanced Research in Computer Science and Software Engineering, 5*(1), 59–65.

Plantak Vukovac, D., Kirinic, V., & Klicek, B. (2010). A comparison of usability evaluation methods for E-learning systems. In B. Katalinic (Ed.), *DAAAM International Scientific Book* (pp. 271–288). DAAAM International: Vienna.

Prougestaporn, P., Visansakon, T., & Saowapakpongchai, K. (2015). Key success factors and evaluation criterias of E-learning websites for higher education. *International Journal of Information and Education Technology, 5*(3), 233.

Pruengkarn, R., Praneetpolgrang, P., & Srivihok, A. (2005). An evaluation model for E-learning websites in Thailand University. In *Fifth IEEE international conference on advanced learning technologies, 2005 (ICALT 2005)* (pp. 161–162). IEEE.

Shee, D. Y., & Wang, Y. S. (2008). Multi-criteria evaluation of the web-based E-learning system: A methodology based on learner satisfaction and its applications. *Computers & Education, 50*(3), 894–905.

Syamsuddin, I. (2012). Fuzzy multi criteria evaluation framework for E-learning software quality. *Academic Research International, 2*(1), 139–147.

Zhang, D., & Nunamaker, J. F. (2004). A natural language approach to content-based video indexing and retrieval for interactive E-learning. *IEEE Transactions on Multimedia, 6*(3), 450–458.

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