Expert Systems with Applications 36 (2009) 10657–10662

Contents lists available at ScienceDirect

Expert Systems with Applications

journal homepage: www.elsevier.com/locate/eswa

Evaluation of the criteria and effectiveness of distance e-learning with consistent fuzzy preference relations

Ru-Jen Chao *, Yueh-Hsiang Chen

The Department of Information Management, Kao-Yuan University, 1821 Chung-San Rd., Lu-Chu Township, Kaohsiung County, 821, Taiwan, ROC

ARTICLE INFO

Keywords:
Consistent fuzzy preference relations (CFPR)
Criteria
Comparison
Distance e-learning
Factor

ABSTRACT

The electronic learning (e-learning) has gradually become more and more important in today's school in Taiwan. Many colleges and universities offer distance e-learning courses or programs for students. An effective teaching or learning through a distance web e-learning system depends on many factors (or criteria). The analytic hierarchy process (AHP) model is suitable for dealing with the multi-criteria problems. This paper utilizes the consistent fuzzy preference relations (CFPR) in AHP model to evaluate these factors. The CFPR is computational simplicity and guarantees the consistence of decision matrices. Rating the criteria is important. An empirical example using CFPR in AHP model to find the weights is presented. The weight can point out which factor is important, especially when the time, manpower, and financial support are limited. The rating results can be directly used to evaluate the distance e-learning effectiveness and can provide teachers and decision-makers in schools important information for improving e-learning practice in the future.

1. Introduction

Along with the advancement of information technology, the electronic learning (e-learning) has played an important role in teaching and learning, which has become more and more popular not only in different levels of schools but also in various commercial or industrial companies in Taiwan. Why e-learning is so popular and become more and more important nowadays? One of the essential factors is that e-learning provides expediency for learners to study courses or learn professional knowledge without the constraint of time and space, especially in an asynchronous distance e-learning system. The other important factor is that e-learning may save internal training cost for some enterprises organizations in a long-term strategy. Also, the e-learning can be used as an alternative self-training for assisting or improving the traditional classroom teaching. Therefore many schools and businesses in Taiwan invest manpower and money in e-learning to enhance their hardware facilities and software contents. As a result various e-learning materials in different scientific areas were produced by teachers, multimedia material designers, or consultant companies. Many schools offer a variety of e-learning courses to students. In addition, the e-learning program has also become a strategy to recruit new students in night schools for some private universities or colleges.

Weather or not the e-learning indeed reaches the goal of teaching or learning relies on many factors (e.g. Govindasamy, 2002; Ong, Lai, & Wang, 2004; Selim, 2007; Sun, Tsai, Finger, Chen, & Yeh, 2008; Tzeng, Chiang, & Li, 2007; Wang, 2003; Wang, Wang, & Shee, 2007). For example: Wang (2003) developed a general instrument for measuring student satisfaction in an e-learning system, in which a 17-item instrument was summarized purified from a 24-item instrument (with 2 global items excluded). This 17-item was grouped into four main categories: (1) learner interface, (2) learning community, (3) content, and (4) personalization. Wang's assessment was used in an asynchronous electronic learning system for commercial companies. Tzeng et al. (2007) also summarized a total of 58 criteria grouped into nine major factors for an empirical e-learning program used in commercial companies and the nine factors were (1) personal characteristics and system instruction, (2) participant motivation and system interaction, (3) range of instruction materials and accuracy, (4) webpage design and display of instruction materials, (5) e-learning environment, (6) webpage connection, (7) course quality and work influence, (8) learning records, and (9) instruction materials.

Most researchers use statistical methods or linear models to determine and evaluate the affecting factors and e-learning effectiveness. Fuzzy set theory has been developed for decades since Zadeh (1965) and was widely used in various scientific fields. Tzeng et al. (2007) developed a hybrid multi-criteria decision making (MCDM) to evaluate the relations and weights of the factors. In MCDM, the factor analysis, decision making trial and evaluation laboratory (DEMATEL), fuzzy integral, and analytic hierarchy

* Corresponding author.
E-mail addresses: chaorj@cc.kyu.edu.tw (R.-J. Chao), chris@cc.kyu.edu.tw (Y.-H. Chen).

0957-4174/$ - see front matter Crown Copyright © 2009 Published by Elsevier Ltd. All rights reserved.
doi:10.1016/j.eswa.2009.02.047

process (AHP) (Saaty, 1980) were employed for factor analysis and e-learning evaluation. The entire hybrid MCDM procedure seems a little complicated in computation.

Evaluation of an e-learning effectiveness primarily contains four portions: (1) determination of the affecting factors, (2) questionnaire collection and statistical analysis, (3) weighting these factors, and (4) evaluation of the entire performance according to these weighted factors. For the first portion (determination of the affecting factors), these factors have been studied by many researchers and they are generally similar with some differences based on the different requirements of e-learning practice in different organizations or universities. Therefore, for (1) determination of the affecting factors, authors of this paper suggest that either use those methods presented by previous researchers to obtain the affecting factors or directly and carefully use those factors with some modifications according to the real practice in his/her organization or university. After the factors determined and questionnaires collected, the weights of these factors can be computed by using any suitable method. Finally, the entire e-learning effectiveness can be evaluated according to these weights. Weighting the factors is important. This study mainly concentrates on the third portion, i.e., the methodology of the weight-rating for each affecting factor. The practices in each organization or university can be different. In addition, frequently, the time, cost, manpower, software, hardware, and etc. can not be satisfied totally. In such case, weighting the factors of an e-learning and a fast easy weighting and evaluation method is crucial because it can be quickly and objectively shown the priority of each factor. The rating results of the distance e-learning can provide significant information to teachers and decision-maker in schools for improving e-learning programs in the future practice.

2. Objective

This study proposes a simple and easy method to weight the factors in an e-learning program or system and then evaluate the overall e-learning effectiveness. The structure of the factors still uses the AHP (analytic hierarchy process) model. The selected method is the consistent fuzzy preference relations (CFPR) (Herrera-Viedma, Herrera, Chiclana, & Luque, 2004). This study use CFPR in an AHP structure to find the weight of the affecting factors (or criteria) in a distance e-learning system. Using CFPR in AHP model is because it is computational simplicity and because it preserves the consistency of comparisons compared with the traditional AHP method. The "computational simplicity" means that it only involves basic calculations (addition, subtraction, multiplication, and division) plus the mathematical logarithm function for transformation.

The rest of the paper is constructed as follows: the CFPR method and e-learning evaluation method will be introduced in detail in Sections 3 and 4, respectively. The criteria in AHP structure is described in Section 5. In Section 6, an empirical example using CFPR in AHP is illustrated in detail to demonstrate the computational simplicity of CFPR. A discussion for the rating result is offered in Section 7. Section 8 concludes this study.

3. Consistent fuzzy preference relations

Analytic hierarchy process (AHP) is a multi-criteria decision-making method (Saaty, 1980), and is primarily used to solve problems involving many comparisons of criteria. In AHP, a questionnaire needs to include $C_2^n = n(n-1)/2$ questions for every grouped n-criterion pairwise comparison. As long as the n increases or such n-criterion group increases, the pairwise comparison increases. It may cause evaluators mental confusion or inconsistent situations because of too many questions and comparisons. In the case of inconsistencies, questionnaires have to be re-answered again, which leads to time wastage and inefficiency.

To avoid the aforementioned problem, this study utilizes consistent fuzzy preference relations (CFPR) (Herrera-Viedma et al., 2004) to establish the pairwise comparison matrices. This approach constructs the decision matrices of pairwise comparisons using additive transitivity. Only $n-1$ comparisons are required to be answered by evaluators. The remaining $(n-1)(n/2-1)$ values of pairwise comparisons of each n-criterion can be derived by using CFPR method, which only involves simple calculations and the procedure guarantees a consistent result in comparisons.

3.1. Preference relations

Preference relations (PR) enable a decision-maker to give values for a set of criteria and a set of alternatives. The value represents the preference degree of the first alternative to the second alternative. Basically, there are two kinds of preference relations applied in the problems of decision-making: multiplicative preference relations and fuzzy preference relations.

Multiplicative preference relations (Saaty, 1980; Chiclana, Herrera, & Herrera-Viedma, 1998): A multiplicative preference relation R in terms of a set of alternatives X is represented by a matrix R. R can be obtained by

$$R \subseteq X \times X, R = (r_{ij}), \quad \forall i,j \in \{1,\ldots,n\}, \tag{1}$$

where r_{ij} is the preference ratio of alternative x_i to x_j. Saaty suggests measuring r_{ij} using a ratio scale with 1–9 scales (Saaty, 1980). When $r_{ij} = 1$ represents the equivalence between x_i and x_j; $r_{ij} = 9$ denotes that x_i is absolutely preferred to x_j; $r_{ij} > 1$ denotes that x_i is preferred to x_j. The preference relation R is typically assumed to be a multiplicative reciprocal, that is

$$r_{ij} \cdot r_{ji} = 1, \quad \forall i,j \in \{1,\ldots,n\}. \tag{2}$$

Fuzzy preference relations (Chiclana et al., 1998; Fodor & Roubens, 1994): A fuzzy preference relation P on a set of alternatives X is a fuzzy set on the product set $X \times X$ with membership the function

$$\mu_p : X \times X \to [0,1]. \tag{3}$$

The preference relation is represented by the $n \times n$ matrix $P = (p_{ij})$, where $p_{ij} = \mu_p(x_i,x_j) \forall i,j \in \{1,\ldots,n\}$. Herein, p_{ij} is the preference ratio of alternative x_i to x_j. When $p_{ij} = 1/2$ means that no difference exists between x_i and x_j, when $p_{ij} = 1$ indicates that x_i is absolutely preferred to x_j, and when $p_{ij} > 1/2$ indicates that x_i is preferred to x_j. The fuzzy preference matrix P is generally assumed to be an additive reciprocal, that is,

$$p_{ij} + p_{ji} = 1, \quad \forall i,j \in \{1,\ldots,n\}. \tag{4}$$

Inconsistency may happen in traditional decision matrices. To solve inconsistency, the consistent fuzzy preference relations (CFPR) (Herrera-Viedma et al., 2004) is used to construct the decision matrices of pairwise comparisons based on additive transitivity. There are three important propositions in CFPR.

3.2. Consistent fuzzy preference relations

Proposition 1. *Consider a set of alternatives, $X = \{x_1,\ldots,x_n\}$, associated with a reciprocal multiplicative preference relation $A = (a_{ij})$ with $a_{ij} \in [1/9,9]$. Then, the corresponding reciprocal fuzzy preference relation, $P = (p_{ij})$ with $p_{ij} \in [0,1]$ associated with A is given as $P = g(A)$, i.e.,*

$$p_{ij} = g(a_{ij}) = \frac{1}{2}(1 + \log_9 a_{ij}), \tag{5}$$