Application of Fuzzy Analytic Hierarchy Process in Ranking Modern Educational Systems' Success Criteria

Mohammad Reza Mehregan, Mona Jamporazmey, Mahnaz Hosseinzadeh, and Mohsen Mehrafrouz

***Abstract*—by advancing information and communication technology (ICT), e-learning has emerged as a modern educational paradigm. This online learning environment improves the delivery of teaching content, knowledge sharing among trainees, social interaction and so forth. Regarding mass investment for e-learning solutions which don't meet their original objectives, e-learning performance assessment remains crucial. E-learning appraisal assists managers of educational institutes by revealing weak and strength aspects of these initiatives and creates opportunity to improve and make effective e-learning systems.**

This paper aim is to introduce a new approach to e-learning system assessment by identifying and prioritizing the preliminary e-learning critical success factors (CSFs) or enablers that need to be concentrated by universities and educational institutes. The result of such performance evaluation subsequently acts as an informative tool for developing e-learning systems plan.

***Index Terms*—E-learning, Critical Success Factors (CSF), Fuzzy analytic hierarchy Process (FAHP).**

I. Introduction

In the recent years, the interest in e-learning tools, designing and implementing e-learning methods has been increased [1]. These systems allow people for ''learning far away'', and they have been frequently designed and used in higher education [1].

Information technology (IT) is playing an important role in recent educational evolution via providing more efficient, effective and modern way of student learning, IT has been viewed as a solution for cost and quality issues of universities [2]. The main reasons of rapid growth of e-learning can be summarized as follows: an opportunity for overcoming the limitations of traditional learning, such as geographical distance, time, budget or busy program; equal opportunities

For getting education no matter where you live, how old you are, better quality and a variety of lecture materials; use shared resources and the students can receive knowledge, skills and experience from other universities [1] -learning has been viewed as the use of the Information and Communication Technologies (ICT) to improve the quality of learning by facilitating access to resources and services, as well as remote exchanges and collaboration [2]

These e-learning systems gather a huge deal of information; which is worthy in evaluating students, performance and assisting teachers to detect of possible errors, shortcomings and finally get improvements [1]

Worldwide, the e-learning market has a growth rate of 35.6%, but failures exist [1]. Although some researchers believe e-learning students learn as well as students of traditional methods, e-learning courses have some limitations which must be reveal and amend [1]. For instant, many online courses cannot sufficiently motivate students to participate, in other word, web based education (e-learning) is apt to isolate trainees and this feature lead to high rate of failure. By considering increasing investment on e-learning solutions, it is important to know how evaluate e-learning programs and overcome their shortcomings [1]. Many researchers have studied several aspects of e-learning and many different approaches were adopted to assess e-learning performance and outcomes [1], [1], [2].

As Strand & Thune [1] notify that evaluation process answers questions such as: Are new technologies producing better learning than traditional classrooms and traditional teachers? Or, are claims of radical improvements in learning as a result of ICT only empty words aimed at making people believe in the utility of ICT and buy more technology? The costly high failure rate of e-learning implementations [6], [1] and some perceived deficiencies of e-Learning [7] make performance evaluation of e-learning as a crucial issue.

One way of facing these challenges is identifying critical success factors of e-learning. Implementing CSFs is vital to achieve success. Critical Success Factors (CSF) entitle something which must be implemented if companies want to be successful. These factors should be controllable and measurable and also few in number [3]. The factors affecting e-learning performance presented by previous studies are basically focused on certain perspectives [6], [12]. This paper has two main contributions: first, proposing a comprehensive approach for assessing e-learning initiatives by using CSF methodology and FAHP method and second, prioritizing the importance of each CSF from e-Learner's viewpoints. To get these aims, the paper combines tow well known managerial methodologies, fuzzy AHP and critical success factors.

The analytic hierarchy process (AHP) is one of the most widely used multiple-criteria decision-making (MCDM) methods. Because of the uncertainty and vagueness as well as imprecision of human decision making in daily life decisions, a fuzzy AHP (FAHP) is used to add with the CSF.

The remainder of the paper is organized as follows:

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Section 2, briefly reviews CSF and fuzzy AHP literature. Section 3, introduces research methodology and data collection. In section 4, the gathered data is analyzed. In section 5, conclusion extracted from survey is argued.

II. Background

A. Definition of e-learning

Recent studies expose that yearly organizations approximately spend 40 billion dollars on e-learning and other technology-based learning programs. Furthermore, more than three million students registered in web based learning courses and large companies saved million dollars yearly [8]. E-learning is a new educational trend and also a challenge for traditional learning. E-learning has been viewed synonymous with web-based learning (WBL), online learning, advanced distributed learning, open/flexible learning, internet-based learning (IBL) [8]. Volery and Lord [1] define e-learning as a combination of learner, faculty, instructor, technical staff, administrative, learner support, and use of the Internet and other technologies. E-learning can be defined as learning initiatives which offer educational materials through online repositories where course interactions and communications are technology mediated [8]. Keramati et al. [1] consider e-learning as a new method of training which complements traditional methods and its final ambition is to build an advanced society for citizens and support creativity and innovation. Martinez-Torres et al. [2] asserte that Multimedia tools, web educational environments, simulation environments, and the distance education have turned into viable educational methodologies, increasing flexibility, accessibility, adaptability, and eliminating the spatial and temporary restrictions of the educational process

E-learning has two aspects: The first aspect is related to structural issues (technology, learning process, learning design) and the other one is related to communicational issues (trainees habits, skills and communication patterns) [7].

B. E-learning Critical Success Factor (ECSF)

Issues related to efficiency, effectiveness and cost are as a driver force for organizations and universities to implement e-learning initiatives [1]. E-learning as an application of IT is integrated with many universities programs [3]. By corresponding, considerable e-learning growth, many researchers from psychology and information system fields have identified important variables dealing with e-Learning success [6]. For instance Thurmond et al [1] introduced some factors which affect e-trainee satisfaction namely Computer skills, courses taken, initial knowledge about e-learning technology, live from the main campus of the institution, age, receive comments in a timely manner, offer various assessment methods, time to spend, scheduled discussions, team work, acquaintance with the instructors. Lau & Tsui [1] declare that knowledge management can enhance e-learning effectiveness. Knowledge management tools such as community, social software, peer-to-peer and personalized knowledge management are now commonly being used in ubiquitous learning. Learners use these tools to generate and share ideas, explore their thinking, and acquire knowledge from other learners.

The rationale behind of e-learning initiatives, like any other learning approach, is to realize the learning objectives. The success criteria of e-learning measures can be environmental, technological, student related, and instructor related [11]. In e-learning some of CSFs are related to technological issues like board band width, reliability of hardware, accessibility, network security, and another success factor is the level of trainees participation and other success factor is related to trainee characteristics like student' commitment and motivation and also their learning speed [3]. Soong et al. [1] use some case studies to identify e-learning CSF and they assert that human factors, technological skill of instructor and student, instructor's attitude and student's attitude to e-learning degree of collaboration, IT infrastructure are most important factors to e-learning success. Picoli et al.[1] site individual features of trainee such as maturity and ability to work with computer and design/technology features such as reliability of technology and individual interactions have significant effects on e-learning effectiveness. According to the studies of Picoli et al [18], Johnson et al [8] also highlight the importance of interacting and participating educational environment and mention trainees features and technology have influence on e-learning outcomes. Table (1) shows briefly some studies about e-learning CSFs.

Based on comprehensive study by Mosakhani and Jamporazmey [7], this paper groups CSFs of e-learning in to seven categories. CSFs and their related indicators are mentioned as following: Instructor characteristics (Instructor attitude to student, Instructor attitude to e-learning, Computer skill), Student characteristics (Computer skill, motivation, commitment, learning speed), Content quality (Updated content, sufficient content, understandable content), Information technology quality (reliability, accessibility, degree of guidance, design of user interface, network security, and timeliness), Participations Interaction (Learning community, ease of interaction with together), Educational institutes support (Providing financial support, proper feedback, diversity evaluation methods) and Knowledge management (Degree of applying knowledge management tools).

C. Fuzzy Set Theory

Fuzzy Set Theory was first introduced by Bellman and Zadeh in 1965 to deal with the uncertainty and vagueness as well as imprecision of human decision making in daily life decisions [1].

The characteristic function μ_A of a crisp set $A \subseteq X$ assigns a value either 0 or 1 to each member in X. This function $\mu_{\tilde{A}}$ can be generalized to a function such that the value assigned to the element of the universal set X fall within a specified range i.e $\mu_{\tilde{A}}: X \to [0,1]$ The assigned value indicate the membership grade of the element in the set A.

The function $\mu_{\tilde{A}}$ is called the membership function and the set $\tilde{A} = \left\{\left(x, \mu_{\tilde{A}}(x)\right); x \in X\right\}$ defined by $\mu_{\tilde{A}}(x)$ for each $x \in X$ is called a fuzzy set [1].

A fuzzy number is said to be a triangular fuzzy number if Its membership function is given as

TABLE I: SOME OF E-LEARNING CSF STUDIES

Author(s)	Critical Success Factors
Dillon and Guawardena [2]	technology, instructor characteristics, student characteristics
Volery and Lord [13]	Technology, instructor, previous use of technology from student's perspective
Soong et al [17]	Human factors, teacher and student s technical competency, attitude of teacher and student about e learning courses, cooperation level, IT infrastructure
Govindasamy [2]	Institutional support, course development, teaching and learning, course structure, student support, faculty support, and evaluation and assessment
Selim [3]	Instructor, student, information technology, and university support
Shee & Wang [2]	Learner interface, learner community, system content, personalization
Sun et al [6]	Learner dimension, Instructor dimension, Course dimension, Technology dimension, Design dimension, Environmental dimension
Ozkan & Koseler [12]	System quality, service quality, content quality, learner perspective, instructor attitudes, supportive issues
Mosakhani & Jamporazmey [7]	Instructor characteristics, Student characteristics, Content quality, Information technology quality, Participations Interaction, Educational institutes support, Knowledge management

$$\mu_{\widetilde{M}}(x) = \begin{cases} \frac{x-l}{m-l} & l \leq x \leq m \\ \frac{u-x}{u-m} & m \leq x \leq u \\ 0 & otherwise \end{cases} \quad (1)$$

Consider two triangular fuzzy number M_1 and M_2, $M_1 = (l_1, m_1, u_1)$ and $M_2 = (l_2, m_2, u_2)$. The arithmetic operations between the two triangular fuzzy numbers are defined as follows [2]:

$$(l_1, m_1, u_1) \oplus (l_2, m_2, u_2) = (l_1 + l_2, m_1 + m_2, u_1 + u_2) \quad (2)$$

$$(l_1, m_1, u_1) \otimes (l_2, m_2, u_2) = (l_1 l_2, m_1 m_2, u_1 u_2) \quad (3)$$

$$(l_1, m_1, u_1)^{-1} = (\tfrac{1}{u_1}, \tfrac{1}{m_1}, \tfrac{1}{l_1}) \quad (4)$$

The analytic hierarchy process, which first proposed by Saaty [2], (AHP) is a decision making approach that considers both qualitative and quantitative data and combines them by decomposing ill-structured problems into systematic hierarchies to rank alternatives based on a number of criteria. This approach has become one of the most widely used multiple-criteria decision-making (MCDM) methods because it provides a proven, effective means for dealing with complex systems related to making a choice, enables the decision-maker to incorporate subjectivity, experience, and knowledge into the decision process in an intuitive and natural way and computes the weight for each criterion and the final weighted average score for each alternative. Since fuzziness and vagueness are common characteristics in many decision-making problems, a fuzzy AHP (FAHP) is used as a complement approach of CSF to develop the framework of prioritizing e-learning systems.

D. Methodology of FAHP

Let $X = \{x_1, x_2, \ldots, x_n\}$ be an object set, and $U = \{u_1, u_2, \ldots, u_n\}$ be a goal set, According to the method of Chang's [2] extent analysis, each object is taken and extent analysis for each goal, g_i is performed, respectively. Therefore, m extent analysis values for each object can be obtained, with the following signs

$$M_{g_i}^1, M_{g_i}^2, \ldots, M_{g_i}^m \qquad i = 1,2,\ldots,n$$

where all $M_{g_i}^j, j = 1,\ldots,m$ are fuzzy triangular numbers.

The steps of Chang`s [23] are briefly represented bellow:

Step 1: The value of fuzzy synthetic extent with respect to the ith object is defined as

$$s_i = \sum_{j=1}^m M_{g_i}^j \otimes \left[\sum_{i=1}^n \sum_{j=1}^m M_{g_i}^j\right]^{-1} \quad (5)$$

where:

$$\sum_{j=1}^m M_{g_i}^j = \left(\sum_{j=1}^m l_i, \sum_{j=1}^m m_i, \sum_{j=1}^m u_i\right), \quad (6)$$

$$\sum_{i=1}^n \sum_{j=1}^m M_{g_i}^j = \left(\sum_{i=1}^n \sum_{j=1}^m l_i, \sum_{i=1}^n \sum_{j=1}^m m_i, \sum_{i=1}^n \sum_{j=1}^m u_i\right), \quad (7)$$

And

$$\left[\sum_{i=1}^n \sum_{j=1}^m M_{g_i}^j\right]^{-1} = \left(\frac{1}{\sum_{i=1}^n \sum_{j=1}^m u_i}, \frac{1}{\sum_{i=1}^n \sum_{j=1}^m m_i}, \frac{1}{\sum_{i=1}^n \sum_{j=1}^m l_i}\right) \quad (8)$$

Step2: the degree of possibility of $M_1 \geq M_2$ is defined as

$$V(M_1 \geq M_2) = \underbrace{\sup}_{x \geq y} [\min\left(\mu_{M_1}(x), \mu_{M_2}(y)\right)] \quad (9)$$

Since M_1 and M_2 are convex fuzzy numbers, then

$$V(M_1 \geq M_2) = 1 \quad if\ m_1 \geq m_2, \quad (10)$$

$$V(M_2 \geq M_1) = hgt(M_1 \cap M_2) = \frac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)} \quad (11)$$

To compare M1 and M2, we need both the values of

$$V(M_1 \geq M_2)$$

and

$$V(M_2 \geq M_1).$$

Step3: The degree possibility for a convex fuzzy number to be greater than k convex fuzzy numbers M_i (i = 1, 2, . . . , k) can be defined by

$$V(M \geq M_1, M_2, \ldots, M_k) = V[(M \geq M_1) and\ (M \geq M_2) and \ldots (M \geq M_k) = minV(M \geq M_i) \quad i = 1,2,\ldots,k \quad (12)$$

Assume that

$$\acute{d}(A_i) = \min(S_i \geq S_k)$$

For $k = 1, \ldots, n\, ; k \neq i$ the the weight vector is given by

$$\acute{W} = (\acute{d}(A_1), \acute{d}(A_2), \ldots, \acute{d}(A_n))^T \quad (13)$$

where A_i (i = 1, 2 . . . . . n) are n elements.
Via normalization, we get the normalized weight vectors

$$W = (d(A_1), d(A_2), \ldots, d(A_n))^T \quad (14)$$

where W is a no fuzzy number.

III. Research Methodology and Data Collection

Data gathered via questionnaire survey. The questionnaire contains proposed CSF indicators and their criteria. The questionnaires were distributed among sample e-learners and ask them for comparing the importance of each CSF indicator to another one and compare the importance of each criterion under each indicator to the other one at the same indicator. The scale used in this questionnaire is presented in table 2. Surveys were sent to 235 e-learners in 4 universities offering e-learning courses via email which 200 of them were received back. So the respond rate is approximately 85%. To calculate the final score of each indicator and criterion, the arithmetic operations between triangular fuzzy numbers is used. Then answers are analyzed by FAHP method. To simplify calculations a FAHP program which is developed by the authors is applied.

IV. Findings

The final score of the pair-wise comparison among indicators and among criteria are input to the FAHP software developed by the authors. Figure 1 shows the pair-wise comparison matrix related to the "Student Characteristics". The final weights of criteria and indicators are summarized in tables 3, 4, 5, 6, 7, 8, 9and10.

TABLE 2: THE FAHP QUESTIONNAIRE SCALE USED FOR PAIRWISE COMPARISON

(1,1,1)	E	Equal
$(\frac{1}{2}, 1, \frac{3}{2})$	EI	Equally Important
$(1, \frac{3}{2}, 2)$	WMI	Weakly More Important
$(\frac{3}{2}, 2, \frac{5}{2})$	SMI	Strongly More Important
$(2, \frac{5}{2}, 3)$	VSMI	Very strongly More Important
$(\frac{5}{2}, 3, \frac{7}{2})$	AMI	Absoloutly More Important

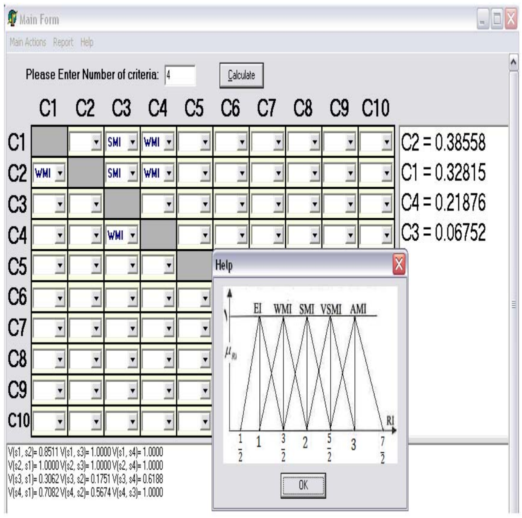

Fig. 1.the software output of FAHP calculation related to Student Characteristics.

TABLE3: THE WEIGHTS OF THE CRITERIA UNDER STUDENT CHARACTERISTICS.

Items	Criteria	weights
C1	Computer skill	0.32815
C2	Motivation	0.38558
C3	Commitment	0.06752
C4	Learning speed	0.21876

TABLE4: WEIGHT OF THE CRITERIA UNDER INSTRUCTOR CHARACTERISTICS.

Items	Criteria	weights
C1	Instructor attitude to students	0.310165
C2	Instructor attitude to e-learning	0.18552
C3	Computer skill	0.504315

TABLE5: WEIGHT OF THE CRITERIA UNDER CONTENT QUALITY.

Items	Criteria	Weights
C1	Update content	0.36879
C2	Sufficient content	0.26356
C3	Understandable content	0.36765

TABLE6: WEIGHT OF THE CRITERIA UNDER INFORMATION TECHNOLOGY QUALITY.

Items	Criteria	weights
C1	Reliability	0.14132
C2	Accessibility	0.16798
C3	Degree of guidance	0.21186
C4	Design of user interface	0.09665
C5	Network security	0.12052
C6	Timeliness	0.26167

TABLE7: WEIGHT OF THE CRITERIA UNDER PARTICIPATION INTERACTION.

Items	Criteria	weights
C1	Learning community	0.68421
C2	Ease of interaction with together	0.31579

TABLE8: WEIGHT OF THE CRITERIA UNDER EDUCATIONAL INSTITUTES SUPPORT.

Items	Criteria	weights
C1	Providing financial support	0.68421
C2	Proper feedback	0.31579

TABLE9: WEIGHT OF THE CRITERIA UNDER KM.

Items	Criteria	weights
C1	Degree of applying knowledge management tools	1

TABLE10: WEIGHT OF THE SEVEN MAJOR CSFS

Items	Criteria	weights
C1	student characteristics	0.24456
C2	IT quality	0.21747
C3	instructor characteristics	0.19169
C4	content quality	0.13361
C5	Educational institutes support	0.11283
C6	participation interaction	0.05612
C7	KM	0.04372

The final ranking of the CSF of e-learning systems and their criteria are summarized in figure (2).

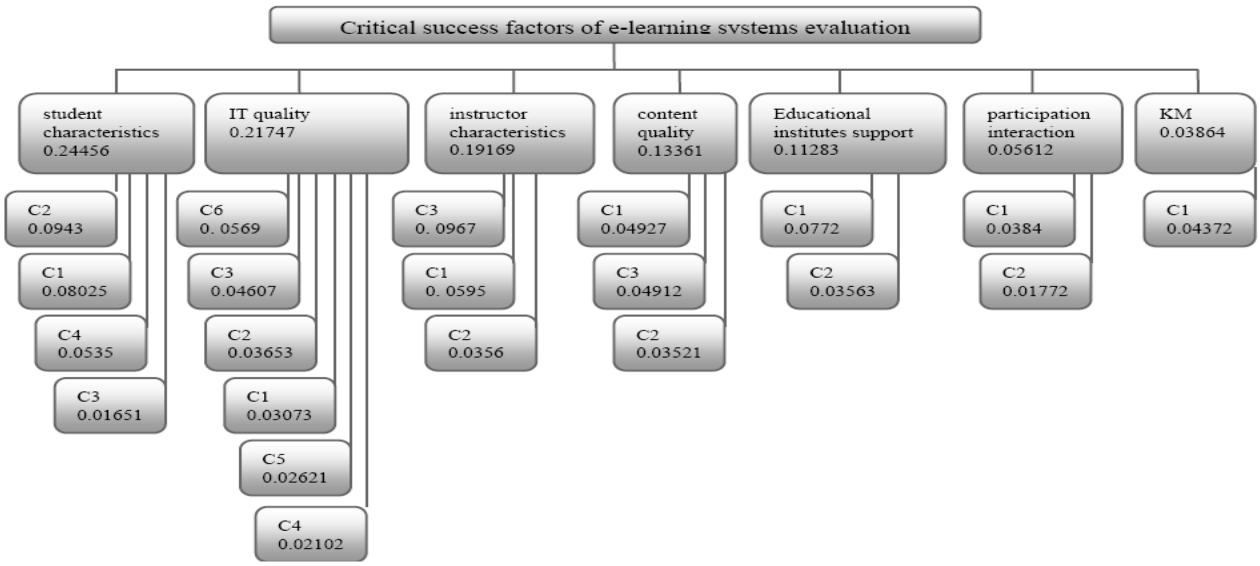

Fig .2. the final ranking of the critical success factors and their criteria for e-learning systems evaluation

V. CONCLUSION

By regarding dynamic and changing environment, successful educational organizations and institutes are those who manage and integrate learning systems continuously to gain learning objects and superior performance. The emergence of e-learning has brought vitality to traditional teaching, because it has a great advantage in knowledge transformation, classroom teaching, social interaction. This paper proposes an approach based on the FAHP and CSF for evaluating the performance of e-learning. The analytic hierarchy is structured by the seven major CSFs including Instructor characteristics, Student characteristics, Content quality, Information technology quality, Participations Interaction, Educational institutes support, Knowledge management followed by sub categories of CSFs.

The results show that student characteristics and IT quality have higher weightings and instructor characteristics, content quality, educational institutes support, participation interaction and KM are in the next priorities of importance. For sub measures, “computer skills” and “motivation” of students as well as “providing financial support from educational institutes” are the most important factors to be focused on. A prioritized list of CSFs was used to guide vendors to design and develop better systems and also assist managers to improve and justify existing e-learning systems. This approach for evaluation provides opportunity for educational institutes and universities to concentrate on key issues and it can also offer beneficial information in strategic planning of e-learning initiatives.

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