

THE DOMAINS FOR THE MULTI-CRITERIA DECISIONS ABOUT E-LEARNING SYSTEMS

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ABSTRACT

Developments in computer and information technologies continue to give opportunities for designing advanced E-learning systems while entailing objective and technical evaluation methodologies. Design and development of E-learning systems require time-consuming and labor-intensive processes; therefore any decision about these systems and their analysis needs systematic and structured guidance to lead to better decisions. Multi-Criteria Decision Analysis (MCDA) techniques are applicable in instructional technology-related research areas as well as in other academic disciplines. In this study, a conceptual domain model and a decision activity framework is proposed for E-learning systems. Instructional, technological, and administrative decision domains are included in this model. Finally, an illustrative example is given to show that AHP is an effective MCDA method for E-learning-related decisions.

Keywords: E-learning, Multi-Criteria Decision Analysis

INTRODUCTION

Humans have to make decisions to select or act on something for different purposes, ranging from simple to complex, conscious to unconscious. At one time or another, all individuals have wished that a difficult decision was easy, and that there was a simple and straightforward way to follow up. For example, in purchasing a utility, there are many factors to consider, such as price, flexibility, brand name, support of manufacturer, etc. Factors such as complexity, uncertainty, multiple objectives, and different perspectives in decision-making constitute the basic sources of difficulty (Clemen, 1996). In this type of multi-factor decision-making, a person may consider the various factors intuitively or subjectively, while feeling the need for a quantitative approach. Most of the decision problems include a number of factors requiring multi-factor evaluation processes. Therefore, a decision process and its analysis need systematic and structured guidance along with the necessary analytical tools that would lead to better decisions.

Developments in computer and information technologies continue to give opportunities for designing advanced E-learning systems while entailing objective and technical evaluation methodologies. One of the difficult decisions that the educators sometimes have to make is deciding on an alternative for E-learning applications. Unqualified instructional software or E-learning practice waste time and resources, and they cannot create effective learning and knowledge transfer (Merrill L, 1996). Functions of the courseware, the application type of E-learning system chosen (web-based, computer-based, mobile learning), or the instructional software itself (simulation, tutorial, problem solving, instructional game etc) generally determine the underlying main evaluation criteria. There are a number of studies dealing with decision problems and the solutions brought to them in many academic disciplines, which are also using individual or integrated multi-criteria decision analysis (MCDA) techniques for a decision making process.

Some of these studies include instructional technology, E-learning and its related research areas, and they research or adopt one of these MCDA techniques to meet the requirements of instructional technology-related decisions. However, the literature review suggests that there is a need for a study using the MCDA techniques with in a high-level decision framework for E-Learning systems.

METHODOLOGY

The goal of this study is to propose a conceptual domain model and a decision activity framework for E-learning systems. The proposed model in this study serves the purposes of describing the important decision domains for E-Learning systems and developing a decision-activity algorithm that includes the E-learning project management, E-learning design and development, and the other processes. Furthermore, an illustrative example is given for selecting the most appropriate E-Learning system based on three quality criteria.

E-LEARNING SYSTEMS

Advances in computer and information technologies have improved the delivery mechanism of teaching materials via electronic media, and have enabled the design of learner-centered and self-paced learning environments while overcoming the obstacles of time and location. Although the review of research and studies about E-learning suggest that there is no exact and clear definition of E-learning, some of the important characteristics that are related to E-learning need to be highlighted.

The most known and common aspect is the technology on which any E-learning system is dependent. Shih et al. (2008) say that "e-learning is the acquisition and use of knowledge distributed and facilitated primarily by electronic means". In the view of some researchers, internet, satellite and the other electronic communication technologies constitute the general framework of E-learning applications.

According to Turvey (2010), technological and managerial definitions seem to portray the E-Learning as a simple delivery mechanism. Therefore, the instructional aspects, such as facilitation of communication between instructors and learners and the constructivist approaches in knowledge-creating mechanism, should be included in the definition criteria.

E-learning systems are also thought to be comprised of different components, through which many of these systems are designed, and where formative and summative evaluation processes are required. One of these components may be the delivery or application type of the E-Learning system. Internet or web-based mediums, local or wide area networking and mobile communicational frameworks generally determine the infrastructure of any E-learning system.

The choice of the delivery type of E-learning will also lead to another decision: It is the naming issue of the E-learning application, whether Computer-Based Training, Internet-Based Training or Web-Based Training; each has sometimes been used as synonymous to E-learning.

The other component is the adoption of an instructional paradigm or the determination of the design criteria to comply with throughout the instructional design processes. The instructional software chosen for the e-learning system, which is related to the application type of E-learning, is distinct from the delivery type choice.

In the literature, there are many studies examining how the research variables pertaining to learners' performance and satisfaction are affected by the instructional software. In a traditional instructional design approach, E-learning systems are developed in a structured and linear fashion.

Analysis, design/development, implementation, and evaluation phases are sharply marked out, where each phase is providing the required input to the next phase. The major drawback of this approach is its rigidity, in which the instructional and system refinements are processed in a linear fashion after or during the design steps. During these design and development phases, instructional technology-related decisions would necessitate using some of the MCDA methods.

MULTI-CRITERIA DECISION ANALYSIS

The definition of MCDA could be "taking the different alternatives or choices of something under consideration in order to make a decision based on a number of standards". The Cambridge Dictionary gives the definition of "criterion" as, "A standard by which a person judges, decides about or deals with something." Within the context of decision analysis, MCDA methods primarily aim at providing the necessary means for organizing complex and conflicting information about alternatives, so that the decision-makers can take all the criteria and factors into account. Belton and Stewart (2002) point out that MCDA is a process, "which makes explicit and manages subjectivity and it integrates objective measurement with value judgment".

MCDA methods have been categorized in different ways. One way is making the distinction between multi-objective and multi-attribute decision-making methods (Mendoza et al., 2006). It is suggested that the main difference is the number of alternatives which the decision methods have been based on.

The multi-attribute methods are designed for choosing the discrete alternatives, where as the multi-objective methods are suited for the infinite number of alternatives defined by a set of constraints. Clemen (1996) regards the multi-objective decision-making as "determining how best to trade off increased value on one objective for lower value on another".

Ho et al. (2010) group the most prevalent MCDA approaches into two main categories in their study, as individual and integrated methods. They ground this study in a review of the literature, which includes the multi-criteria decision-making approaches for supplier evaluation and selection problems. Data envelopment analysis (DEA), linear programming, goal programming (GP), multi-objective programming, analytic hierarchy process (AHP), analytic network process (ANP), simple multi-attribute rating technique, and fuzzy set theory are involved in individual MCDA approaches, whereas the integrated AHP and DEA, integrated AHP and GP, integrated AHP and multi-objective programming, integrated fuzzy and AHP, and finally integrated ANP and multi-objective programming are in the integrated MCDA approaches. One of the best-known general classifications of MCDA methods is the one that Belton and Stewart (2002) made. They classify the methods into three categories:

Value Measurement Models

"Numerical scores are constructed in order to represent the degree to which one decision option may be preferred to another. Such scores are developed initially for each individual criterion, and are then synthesized in order to effect aggregation into higher-level preference models";

Goal, Aspiration or Reference Level Models

“Desirable or satisfactory levels of achievement are established for each criterion. The process then seeks to discover options, which are closest to achieving these desirable goals or aspirations”;

Outranking Models

“Alternative courses of action are compared pair wise, initially in terms of each criterion in order to identify the extent to which a preference for one over the other can be asserted. In aggregating such preference information across all relevant criteria, the model seeks to establish the strength of evidence favoring selection of one alternative over another”. s long as the defined problem or the goal(s) of a decision problem would be the primary determinant of which MCDA method is most appropriate, it is also crucial that decision-makers feel comfortable with the selected MCDA models. A detailed analysis of the MCDA methods and their conceptual foundations is out of the scope of this study.

However, a general outline of most known methods, which are also practically applicable to E-learning decision problems, should be helpful for understanding the decision activity algorithm of the proposed model in this study.

Weighted Sum Model (WSM) is a simple and practical MDCA method that is dependent upon the measure of relative importance of criteria viewed by the decision-maker, which is generally called “weight” (Pomerol et al., 2000). Given that x alternatives and y decision criteria exist in a decision problem, the best alternative is determined by the aggregation of performance value of alternatives and the weights attributed to criteria. Goal programming (GP) is an optimization method used for minimizing the deviations from goals which belong to an objective that has probably conflicting measures with the other objectives’ measures. The overall purpose of GP is to achieve a solution that minimizes these deviations, and it emphasizes trading off criteria (Chang et al., 2009). Data Envelopment Analysis (DEA) is defined as a nonparametric method by which a decision-making unit (DMU) is measured (Ray, 2004). Giannoulis et al. (2010) note that DEA is a ranking technique where normalization is not required. Their argument is that DMU and outputs & inputs could be replaced with alternatives and criteria respectively. Analytic Hierarchy Process (AHP) is one of the main MCDA methods for complex decision-making problems involving subjective judgment. AHP is especially beneficial when people have different perspectives and priorities and components of any decision are not easy to compare or quantify. Analytic Network Process (ANP) and AHP both have iterative pair-wise comparisons to obtain a ranking of alternatives given in a decision problem.

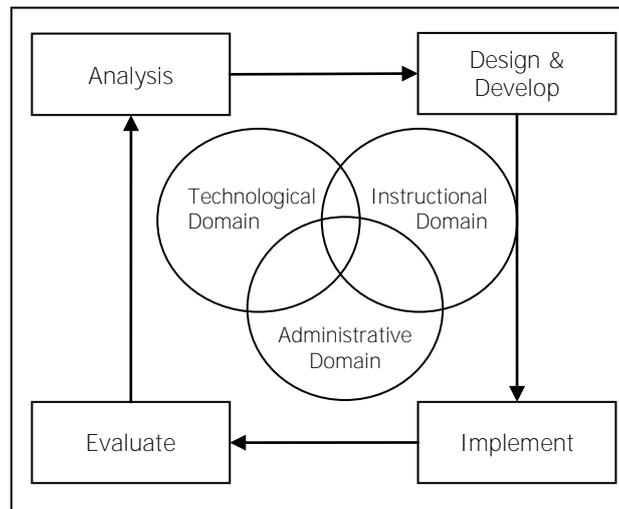
The main difference between AHP and ANP is that the former structures the problem into a hierarchy including a goal, criteria and alternatives, and the latter structures the whole process as a network.

E-LEARNING DECISION DOMAINS

The Decision Domains

It is appropriate to give the dictionary definitions before relating the “domain concept” to E-learning systems. Cambridge Advanced Learner's Dictionary defines domain as “an area of interest or an area over which a person has control”. Longman Dictionary describes this area with activity, interest, or knowledge, especially one that a particular person, organization deals with. The definition in Webster's Dictionary is probably more relevant to our study, “the content of a particular field of knowledge plus the knowledge that you are interested in or are communicating about”.

E-learning systems are thought to be comprised of three main decision domains, which also determine the criteria for E-learning systems: instructional, technological, and administrative decision domains (Figure: 1).



**Figure: 1
E-learning Decision Domains**

The instructional decision domain primarily includes instructional requirements. Task and context analysis, online-course description, and instructional design parameters may be given as determining criteria for this domain.

E-learning application type, development and deployment software architecture, hosting services, multimedia design, etc., constitute the technological domain. The administrative domain has two dimensions: online course management and project management.

While the course management task can be regarded as a low-level administration, the project management-related activities wrap the other processes. Thus, different types of decision-makers, a.k.a. decision actors, may participate in its unique or mutual E-learning decision cases to achieve their goals.

A Use Case Diagram in the Unified Modeling Language (UML) is a type of behavioral diagram that defines the requirements of a system as viewed by the actors; and it is especially very often referred in software engineering design and development processes.

It describes the system's behavior under various conditions, shows a set of use cases and actors and their relationships while modeling the context of the system.

A use case describes what a system does without specifying how it does it. Figure 2 shows the general outline of the decision use cases of an E-learning system, and it depicts how the decision actors accomplish their goals through the use cases.

The main E-learning decision use case is the outcome of the other group of use cases. Instructional, technological, and administrative use cases are included in the first group. E-learning analysis, design and development, implementation, and evaluation use cases are in the second group.

The last group is made up of project management-related use cases, which are project initiation, project planning, project execution, project closure, and project evaluation processes.

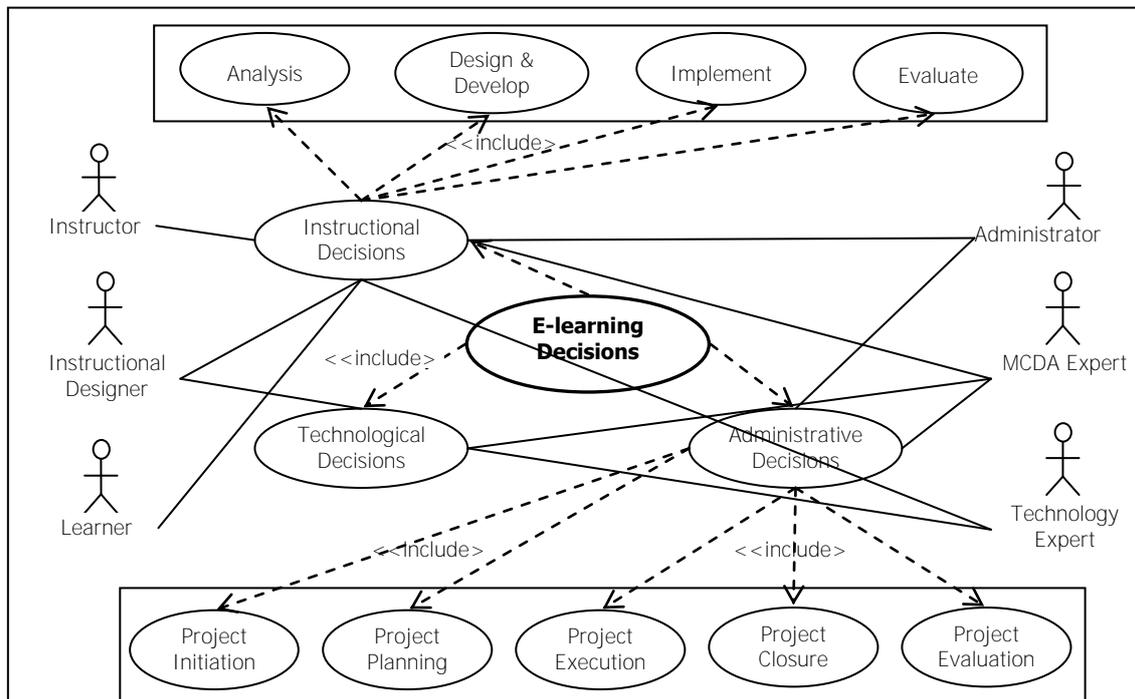


Figure: 2.
E-learning Use Cases with Decision Actors

The uses cases related with instructional, technological, and administrative domains are depicted in elliptical shapes in Figure 2, and they organize the E-learning system’s requirements, analysis and design processes. The “E-learning Decisions” use case is base use case, and it is the kernel of the system including the all sub use cases shown in Figure: 2. Its main sub use cases, which are the instructional, technological, and the administrative ones, have also the other included sub use cases. Project management uses cases (initiation, planning, execution, closure, and evaluation) belong to the “Administration Decisions”. Instructional use cases (analysis, design & develop, implement, evaluate) are in the “Instructional Decisions”. The actors, such as instructors, administrators, and MCDA experts, are drawn in stick figure shapes that are representing the information exchange with use cases. The decision actors of an E-learning system are expected to play different sets of decision roles when interacting with these use cases. For example; the instructor, learner, technology expert, and the instructional designer actors participate in the decisions of task analysis, course description, and design parameters. The administrator actor approaches to an E-learning system from a view point of project management discipline, and she or he primarily concerns with the project related decisions.

The E-learning Decision Activities

The activity diagrams are generally used for the modeling of business processes, activities, and work flows of systems at a high level. It represents the how data move around a system of activities that describe some computational procedures as well as decisions. There are some basic notations specific to activity diagrams.

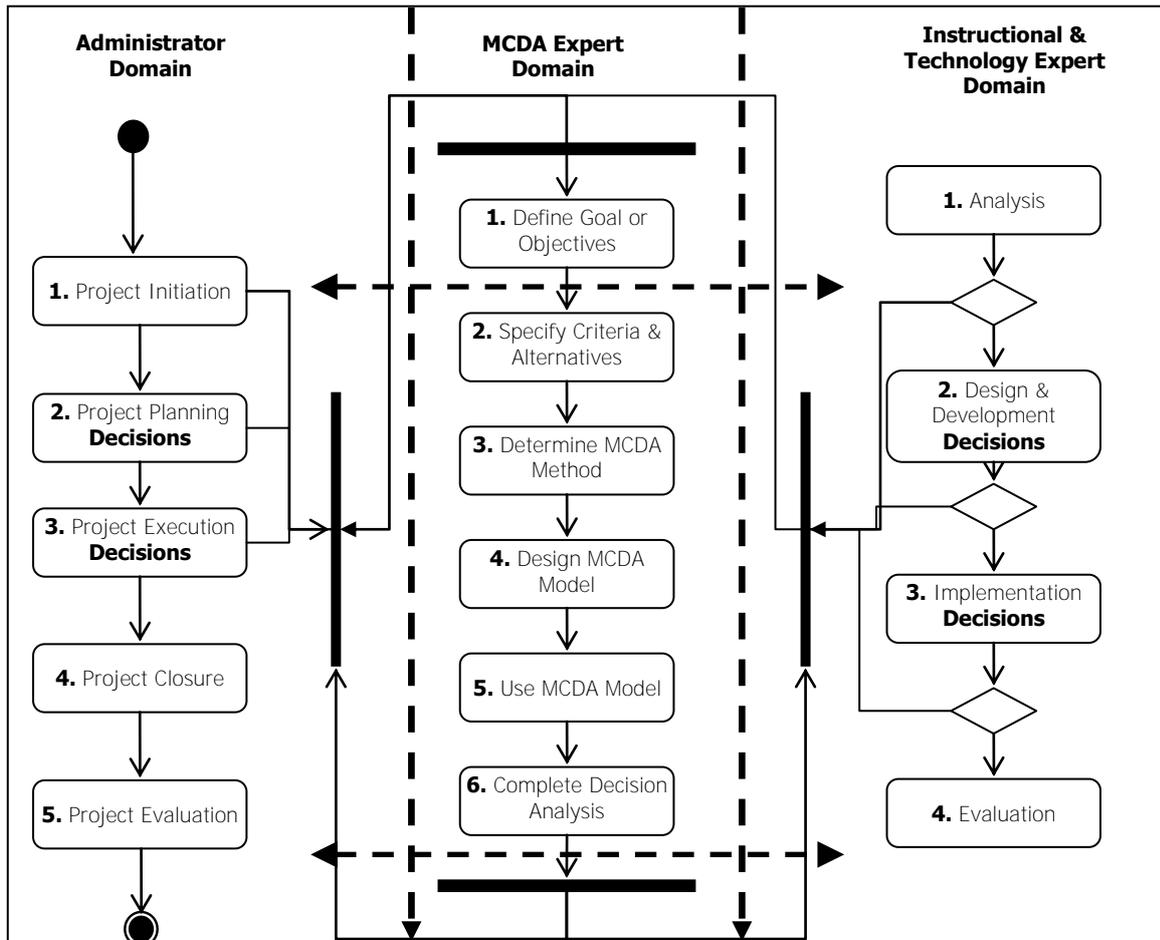


Figure: 3
The Decision Activities for an E-learning Project

The occurring activities are represented by the rounded rectangles, decision points are represented by diamonds, while the black bars represent parallel activities. Figure: 3 shows the swim lanes that are related with the decision domains. Each of the swim lanes groups the processes and decisions of an E-learning decision domain controlled by a decision maker.

The first swim lane includes the administrator domain, and it has the activities that are primarily related with the project management processes. From the project initiation view point, a feasibility study, forming structure, and deciding the objectives of the project are main domain tasks to be put forward. Subjects such as financial and other project resources, quality and acceptance criteria are the issues to be considered at the project planning phase. After forming a project plan, E-learning project activities and the tasks, which are addressed in the project plan, are executed in a series of management processes. Project documentations, post E-learning implementation review and the project evaluation activities take place at the final stage of the administrator domain. Project initiation-execution related issues of the administrator domain are the most probable activities of this domain requiring decision analysis approach, and they are processed in the MCDA expert domain. The second swim lane in Figure 3 is responsible for all decision analysis tasks. The first step is defining the E-learning project goal or objectives. Later at the second step, criteria and alternatives pertaining to E-learning systems are specified.

Determining the proper MCDA method comes after the specifications of criteria. Should we select E-learning application software as a project goal, a multi-attribute MCDA method could be used for choosing one from the discrete software alternatives? The main instructional design and development activities for E-learning systems are included in the third swim lane. Although, analysis, design, development and evaluation phases are marked out, each phase provides the input to the next development phase.

THE ILLUSTRATIVE EXAMPLE USING AHP METHOD

The illustrative example of this study which is also similar to that of Uysal (2010) puts the requirements of any E-learning system into three main groups, which are instructional, technological, and managerial requirements respectively. It is thought that the instructional design, technology, and the managerial functionalities determine the quality criteria for any E-learning system. During the E-learning design and development processes, the need for a quantitative evaluation approach to translate the requirements, subjective or objective expectations of stakeholders into the measured and quantified parameters will lead us to a well known MCDA method, AHP. AHP is a systematic multi-criteria evaluation method developed by Saaty (1980), and has found a wide range of place in many solutions of different problems. It enables individuals to structure complex problems in a form of hierarchy, and it addresses how to determine the relative importance of a set of alternatives in a multi-criteria decision-making environment. AHP helps decision makers to determine the various factors with their weights that are pointing out their importance and laying out the hierarchy of the decision. Its general execution steps are as follows:

- 1st Step: The decision maker starts the overall procedures by defining the problem and setting up the goal related with the problem.
- 2nd Step: She or he determines the criteria reflecting the experts' opinions, and later the hierarchy is structured and reviewed.
- 3rd Step: Iteratively and respectively;
 - The pair wise comparisons are made for each alternative,
 - Criteria weights are calculated,
 - Consistency is checked.
- 4th Step: Finally, the weights of criteria are aggregated and the weights are combined to rank the alternatives for selecting.

The execution steps carried out for the quality-based selection of an E-learning system are shown in Figure: 4.

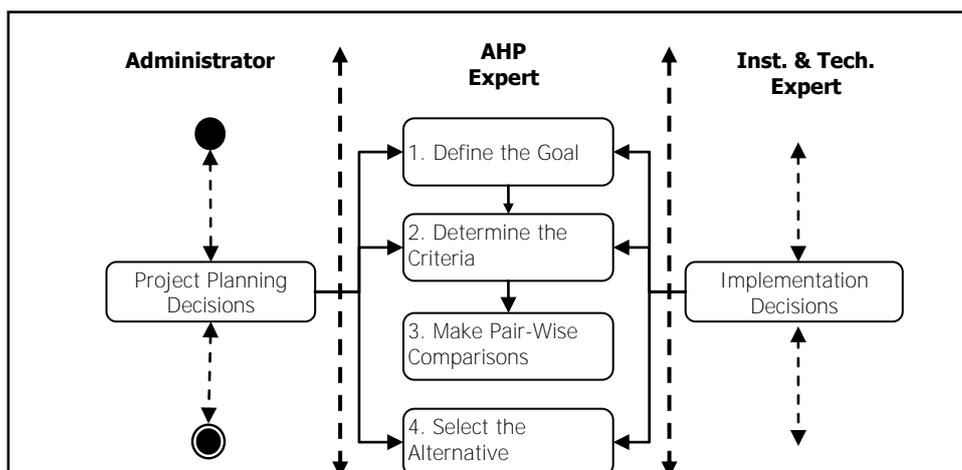


Figure: 4
The AHP Method for Selecting an E-learning System

Step-1: Defining the Goal

It is supposed that the system alternatives are limited from many to three, as E-Learning-1, E-Learning-2 and E-Learning-3 for simplicity purposes in this study. The goal is to select the most appropriate E-Learning system based on the quality criteria.

Step-2: Determining the Criteria

It is possible to determine many main and sub-criteria for the multi-factor evaluation processes. However, these criteria are restricted to three, such as instructional quality, technological quality, and administrative quality for simplicity purposes.

Step-3: Pair-Wise Comparisons

The key issue for AHP is the making iterative pair-wise comparisons. Decision makers need to compare two different alternatives (E-learning system) based on a defined criterion using a scale ranging from 1 to 9. (1 is equally preferred, 2- Equally to moderately preferred, 3- Moderately preferred, 4- Moderately to strongly preferred, 5- Strongly preferred, 6- Strongly to very strongly preferred, 7- Very strongly preferred, 8- Very to extremely strongly preferred, and 9 is Extremely preferred)

E-learning decision maker starts making comparisons by looking at the criterion "instructional quality", and then respectively compare E-Learning systems; E-Learning-1 with E-Learning-2, E-Learning-1 with E-Learning-3, and finally E-Learning-2 with E-Learning-3 for scoring purposes. A pair-wise comparison matrix is to be constructed at the end of these procedures. This matrix reveals the preference for "instructional quality" concerning the three E-Learning system alternatives.

Assuming that the decision maker is an expert on instructional technology, it is determined that the E-Learning-1 is moderately preferred to E-Learning-2, E-Learning-1 is extremely preferred to E-Learning-3, and E-Learning-2 is strongly to very strongly preferred to E-Learning-3 (Table: 1). We place 1 from upper left corner to the lower right corner of the matrix since each E-Learning system is equally preferred to itself. If the E-Learning-1 is moderately preferred to E-Learning-2 and it is scored as 3, and then E-Learning-2 will naturally be preferred to E-Learning-1 with the score of 1/3. The lower left of this matrix is completed using the same logical approach (Table: 2).

Table: 1
Initial Comparisons

Instructional Quality	E-1	E-2	E-3
E-1		3	9
E-1			6
E-1			

Table: 2
Completed Comparison Matrix

Instructional Quality	E-1	E-2	E-3
E-1	1	3	9
E-1	1/3	1	6
E-1	1/9	1/6	1

Evaluations for the Criterion

Evaluation procedures start aftermath of the pair-wise comparisons. E-learning decision maker executes the same evaluation steps iteratively in order that the relative importance of each criterion is determined clearly. Although each criterion needs to be handled individually and the results are combined with the next criterion calculations, decision maker will only focus on the criterion "instructional quality". Because of limitations of this study, the calculations of other criteria will be assumed that they are performed in the same manner. To start and make them easier, we convert matrix numbers to decimals, and then get the column totals (Table: 3). The numbers in the matrix are divided by their respective column totals and a normalized matrix is achieved once the column totals have been found (Table: 4).

Table: 3
Matrix Converted to Decimals

Instructional Quality	E-1	E-2	E-3
E-1	1	3	9
E-1	0.333	1	6
E-1	0.111	0.167	1
Column Totals	1.444	4.167	16.0

Table: 4
Matrix Divided by Column Totals

Instructional Quality	E-1	E-2	E-3
E-1	0.69	0.72	0.562
E-1	0.23	0.24	0.375
E-1	0.07	0.04	0.063

The priorities for "instructional quality" of the three E-Learning systems are determined by finding the average of the rows from the matrix of numbers (Table: 5).

Determining Consistency Ratio for the Criterion

AHP regards the consistency as a cardinal consistency. As an example, if A is thought to be two times more important than B, and B is considered to be three times more important than C, then A should be six times more important than C. If the decision maker judges that A is less important than C, a judgmental error occurs and the prioritization matrix is accepted as inconsistent. Therefore, the Consistency Ratio (CR) is a value, which is indicating that how we are consistent with our answers. A higher ratio means that the decision maker is less consistent, whereas a lower one means she or he is more consistent

Table: 5
Averages of the Rows

Instructional Quality	
Row	$(0.692 + 0.720 + 0.562)/3 = 0.658$
Averages	$(0.230 + 0.240 + 0.375)/3 = 0.282$
	$(0.077 + 0.040 + 0.063)/3 = 0.060$

Table: 6
Decision Matrix for Instructional Design

Criterion	E-1	E-2	E-3
Delivery Type	0.658	0.282	0.060
Instructional Design			
Instructional Software			

In terms of numbers, if the ratio is 0.10 or less, the decision maker's answers are consistent. A consistency ratio with a value higher than 0.10 requires reevaluation of the responses, which are given for the original matrix of pair-wise comparisons. In general, the division of the Consistency Index (CI) by the value of Random Index (RI) gives us the CR. The basic formulas needed for the calculations of the CR are:

$$CR = \frac{CI}{RI} \quad \text{and} \quad CI = \frac{\lambda - n}{n - 1} \quad (1)$$

n is the number of alternatives; RI is the index number obtained from the table with an entry value of n; Lambda (λ) is achieved from the matrix operations of the Weighted Sum Vector and the Consistency Vector as follows:

$$\text{The Weighted Sum Vector} = \begin{bmatrix} (0.658)(1) + (0.282)(3) + (0.060)(9) \\ (0.658)(0.333) + (0.282)(1) + (0.060)(6) \\ (0.658)(0.111) + (0.282)(0.167) + (0.060)(1) \end{bmatrix} = \begin{bmatrix} 2.044 \\ 0.860 \\ 0.180 \end{bmatrix}$$

(2)

$$\text{The Consistency Vector} = \begin{bmatrix} 2.042/0.658 \\ 0.860/0.282 \\ 0.180/0.060 \end{bmatrix} = \begin{bmatrix} 3.103 \\ 3.051 \\ 3.009 \end{bmatrix} \quad (3)$$

$$CI = \frac{\lambda - n}{n - 1} \Rightarrow \lambda = \frac{3.103 + 3.051 + 3.009}{3} = 3.054 \Rightarrow CI = \frac{\lambda - n}{n - 1} = \frac{3.054 - 3}{3 - 1} = 0.027 \quad (4)$$

$CR = \frac{CI}{RI} = \frac{0.027}{0.58} = 0.047$ is obtained by the value found by equation (4) and the value from RI table (Table: 7)

Table: 7
Random Index Table

Number of Alternatives (n)	2	3	4	5	6	7	8	9	10
Random Index (RI)	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.51

It is possible to say that the decision maker is relatively consistent with his responses by looking at the CR, which has the value of 0.047. As a result, CR supports our original assessments of pair-wise comparison matrix.

Evaluations for the Other Criteria

So far, we have completed the evaluations for the criterion instructional quality for all alternatives of E-learning systems. The same calculations could be easily made for the other criteria that are named as technological and administrative quality. Assuming that we have performed the same pair-wise calculations, we end up with the final comparison matrix (Table 8). The next step is the determining the criteria weights.

Rather than deciding them subjectively, the AHP is again an objective method used for finding the weights. Iterative calculation methods and the computations of each CR enable an E-learning decision maker to be sure that he is also consistent with his responses to criteria weights. Table: 9 shows the weights of the criteria, which are also calculated in the same manner.

Table: 8
Pair-wise Comparison Matrix

Criterion	E-1	E-2	E-3
Instructional Quality	0.658	0.282	0.060
		0.750	
Technological Quality	0.087	0.182	
Administrative Quality	0.497	0.398	0.107

Criterion	Weights
Instructional Quality	0.082
Technological Quality	0.682
Administrative Quality	0.236

Table: 10
The Final Decision

Alternatives	Decision Result
E-1	0.231
E-2	0.228
E-3	0.542

Step-4: Selecting the E-learning System

Following the completion of the comparison and criteria weight matrixes (Table: 8 and), the last step is obtaining of the final decision matrix.

It is found by a matrix multiplication including the comparison and the criteria weight matrixes that are shown in Table 10.

It is clear that the *E-Learning-3* received the highest ranking in these calculations, and it should be selected as the best E-Learning system in terms of quality criteria.

CONCLUSIONS

Although advances in computer and information technologies have contributed to E-learning systems in a variety of ways, there are also many factors influencing their effectiveness. The literature review suggests that these factors need to be grouped and processed in a systematic framework, especially when the quality issue comes in to the question.

Additionally, determining the best E-learning system which satisfies all the required criteria is a difficult educational task.

This difficulty arises from the fact that the various systems may have different characteristics, and not only one would possess all the instructional, technical and other functionalities for a qualified E-learning system. Thus, the evaluation of any E-learning system is considered as a complex multi-attribute decision-making problem.

The decisions on E-learning systems need systematic and structured guidance as well as necessary analytical tools that would lead to better decisions. In this study, a decision framework model for E-learning systems is proposed, and this model has associated the instructional, technological, and administrative quality criteria with the corresponding decision domains. Finally, an illustrative example is given to show that AHP is an effective MCDA method as well as it is a promising tool for E-learning-related decisions.

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