Neutrosophic AHP Multi Criteria Decision Making Method Applied on the Selection of Learning Management System

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Abstract

Learning management systems (LMSs) are used today to assist in the designing, delivery and management of learning resources for learners. There are hundreds of LMS available in the marketplace. Selecting the most suitable LMS that meets specific requirements is a problem of decision making. Many studies in learning management system selection are implemented under complete information, while in the real world many uncertainty aspects do exist. As these systems were described by decision makers with vague, imprecise, ambiguous and inconsistent terms, it is understandable that traditional multi criteria decision making methods may not be effective. This paper develops a novel hybrid neutrosophic analytic hierarchy process approach to support facing of uncertainty in the decision making process to handle indeterminacy of information. In order to show the application of the developed method, a numerical experiment for an LMS selection is made using the method of neutrosophic analytic hierarchy process. Results show that the neutrosophic logic is capable of representing uncertainty manner understandable by the human logic. Obtained results have shown that Moodle is the best LMS that meets defined criteria.

Keywords: *Learning Management System; Multi-criteria Decision Making; Uncertainty; Neutrosophic*

1. Introduction

Learning Management Systems (LMSs) are web based applications used to manage the e-learning process, and assist instructors and learners [1]. The use of these applications has increased in higher education as it assists students and instructors to design, share and deliver learning materials [2]. Many universities consider LMSs as useful tools that support spreading educational resources to the learners [3-5]. There are hundreds of LMS products available in the marketplace. Educational institutions try seriously to determine what type of LMS is most appropriate for their requirements [6]. Therefore, there is a need to help institutions with the tools necessary to evaluate the effectiveness of these systems [7,8]. The problem of LMS selection is an example of multi-criteria decision making (MCDM) problem. The traditional crisp MCDM methods are not enough to solve these problems as they cannot handle the uncertainty present in real world cases, when the decision maker has usually vague, imprecise, ambiguous and inconsistent information [9]. Thus it is more reasonable to find a better method to collect the opinions of the decision makers [10].

One of the most popular MCDM methods is Analytical Hierarchy Process (AHP). It divides the problem into a system of hierarchies of objectives, attributes and alternatives. Advantages of the AHP include dealing with tangible and non-tangible attributes, comparing alternatives with relative ease, group decision making problems, adjusting size to accommodate decision making problems due to its hierarchical structure, and checking inconsistencies which are not achieved in other multi criteria decision making such as TOPSIS, VIKOR, PROMETHE and ELECTRE. AHP is a scalable method and although it requires enough data to properly perform pairwise comparisons, it is not nearly as data intensive as multi attribute utility theory (MAUT). The main disadvantage of AHP is incapability of reflecting uncertain human's thoughts. The traditional AHP considers the definite judgments of decision makers, thus the neutrosophic set theory makes the expert's preferences more flexible. [11,12]. This is the disadvantage that this paper focuses on as the problem.

A decision making processes is needed to select the most suitable LMS option from a set of alternatives, due to organizational requirements. Taking a decision would require one to choose the best choice from a set of alternatives a small set of good alternatives, by analyzing the different criteria present [12]. The selection process of an LMS is in general costly, time consuming and exhausting [13]. One of the key issues in decision making is the eliciting of judgments from decision makers. MCDM approaches form major parts of the decision theory and analysis, particularly when the elements of the problem are numerous, and the interrelationships among the elements are extremely complicated [14].

The analytic hierarchy process is a multi-criteria decision making method, used in management science, for determining priorities. AHP was developed by T. L. Saaty. It helps decision makers to decompose a complex problem into a hierarchical structure, and to derive a ratio scale of relative priorities in order to rank them [15]. In the traditional AHP method, the values that are used to compare different criteria are represented by crisp numbers within the 1–9 scale. In a real environment, the decision maker might be unable to determine the crisp values with different criteria, due to the lack of available information [16]. AHP is popular in handling MCDM problems, but it is criticized for its incapability to handle uncertainty in human judgments. To control this issue, fuzzy AHP was introduced, where each pairwise comparison judgment is represented as a fuzzy number that is described by a membership function [17,18,19]. The fuzzy number does not describe the degree of non-membership, and it is not a solution when decision makers are hesitant in defining membership. Antanassov [20] introduced intuitionistic fuzzy sets that are characterized by a membership function and a non-membership function as well. Intuitionistic fuzzy is as vague set which presents fuzzy objects naturally and shows the concept of variability. Therefore, intuitionistic fuzzy AHP is presented by scholars to express the decision makers' opinion to a certain degree. Fuzzy AHP has been applied to many different fields [16,21-23]. The intuitionistic fuzzy set is not able to handle the indeterminacy of information.

Smarandache [24] proposed a new approach as an extension of fuzzy logic, the neutrosophic logic, in which variable x is described by a triple values x= (t, i, f) where "t" it is the degree of truthfulness, "f" is the degree of falsehood, and "i" is the level of indeterminacy [25]. This approach models uncertain data and imprecise information of the real world in different fields, such as web intelligence, decision making, image processing and expert systems. Neutrosophic logic is a better option to simulate human thinking which is equipped to handle indeterminacy [26 - 28]. The decision making process tends to rely not only on true values, but also on false ones as well as on indeterminacy membership. Thus neutrosophic logic holds its chance to simulate human thinking, deal with contradictions that are true and false at the same time [24], and to be utilized for real world problems [29]. The primary uncertainty types are vagueness, impreciseness, ambiguity and inconsistency. An example of vague information would be the following sentence: "The color of the flower is nearly red"; this type of uncertainty can be handled by a fuzzy set. An example of imprecise information would be the following sentence: "The temperature of the machine is between 88-92 °C"; this type of uncertainty can be handled by an intuitionistic fuzzy set. An example of ambiguous information would be the following sentence: "Votes for this candidate reached about 60%". An example of inconsistent information would be the following sentence: "The chance of raining tomorrow is 70%, and that does not mean that the chance of not raining is 30% since there might be hidden weather factors that we are not aware of"; these types of uncertainties can be handled by neutrosophic sets [30].

Neutrosophic logic is a new branch of philosophy which studies the nature of neutralities as well as their interactions with different intellectual idea [24]. For example; A or B voting took place, with some votes being invalid, and it cannot be determined whether they belonged to vote A or B. These unspecified votes could be expressed with neutrosophic logic. Current systems dedicated to simulating the human brain are constrained with strict conditions, whereas the neutrosophic logic might be capable of simulating the human thinking, and might be utilized in the real world. In neutrosophic logic, the sum of the components is not necessarily similar to those in fuzzy logic, but they are a number between –0 and 3+, therefore neutrosophic logic is able to deal with contradictions which are true and false at the same time [31,32].

The purpose of this paper is to extend the AHP method via the neutrosophic set. For Instance, there is a large number of LMSs which feature many technical and pedagogical aspects. Thus an important question to be answered is how can decision makers select the suitable LMS to meet the user needs and the priorities of the educational organization. This question can be answered with in spite of the uncertainty and with the use of MCDM methods as illustrated previously. In this paper, neutrosophic analytic hierarchy process as a novel hybrid method is presented and applied to the LMS selection problem. The main limitation of AHP is its incapability of reflecting uncertain data, thus the neutrosophic set theory is used to express expert's

preferences. The other limitation is deriving neutrosophic division operations which are not presented before.

The structure of this paper is organized in five sections: in Section 1, an introduction is given. Section 2 presents the proposed decision-making method that is based on neutrosophic sets. Developing the neutrosophic analytic hierarchy process method (NAHP) and applying it to the selection of the LMS is detailed in section 3. Section 4 discusses the results. Finally, section 5 presents the conclusion.

2. The Proposed Decision-Making Method Based on Neutrosophic Sets

2.1 Neutrosophic Analytic Hierarchy Process

The AHP method is proposed for the evaluation of the selected LMS products because it provides the managers of education with a less complex, and a more appropriate way to analyze the LMS [32]. It is more natural to decision makers to give flexible judgments than a fixed one. The main disadvantage of AHP is its incapability of reflecting the uncertainty of human thoughts. The traditional AHP method considers the definite judgments of decision makers. While the neutrosophic set theory makes the experts judgments more flexible.

The procedure of the neutrosophic analytic hierarchy process is as follows:

The first step in the proposed NAHP method defines the neutrosophic numbers that correspond to the 1–9 Saaty scale, they are used to compare different criteria.

The second step identifies the criteria, sub criteria and alternatives of the decision-making problem. Then follows the constructing of the hierarchy of the considered problem.

The third step determines the neutrosophic preference via the pairwise comparison between each criterion and sub criterion. Afterwards comes the comparing of the alternatives under each criterion or sub criterion.

The fourth step checks the consistency of each pairwise comparison, and the neutrosophic preference relation is constructed.

The fifth step presents the calculation of the neutrosophic relative weight of each preference relation. The relative weight is calculated by the addition of each column in the matrix, then each number in the matrix is divided on the sum of its column, with averaging across the rows being the last step.

The sixth and last step ranks the overall weights, and a choice is made of the best alternative, by having the structure of the number of alternatives multiplied by the number of criteria.

2.2 Some Concepts of Neutrosophic Sets

Neutrosophic sets describe variable x is described by a triple values x= (t, i, f) where "t" it is the degree of truthfulness, "f" is the degree of falsehood, and "i" is the level of indeterminacy. Neutrosophic logic is able to deal with contradictions which are true and false at the same time, as the sum of the components is any number between –0 and 3+ [24].

In this section, a brief review of the general concepts of neutrosophic set is presented [32, 33]:

Let X be the space of the objects, and $x \in X$. A neutrosophic set A in X is defined by three functions: truthfulness-membership function $T_A(x)$, an indeterminacy- membership function $I_A(x)$ and falsehood-membership function $F_A(x)$.

Definition 1: If $N_1 = (t_1, i_1, f_1)$ and $N2 = (t_2, i_2, f_2)$ are two single valued neutrosophic numbers, then the addition of N_1 and N_2 can be expressed as follows:

$$N_1 + N_2 = (t_1 + t_2 - t_1 t_2, i_1 i_2, f_1 f_2) \qquad (1)$$

Definition 2: If $N_1 = (t_1, i_1, f_1)$ and $N2 = (t_2, i_2, f_2)$ are two single valued neutrosophic numbers, then the multiplication between N_1 and N_2 can be expressed as follows:

$$N_1 \times N_2 = (t_1 t_2, i_1 + i_2 - i_1 i_2, f_1 + f_2 - f_1 f_2) \qquad (2)$$

From equation (2), Authors derived the division operation which is not presented in previous researches as following:

If $N_1 = (t_1, i_1, f_1)$, $N_2 = (t_2, i_2, f_2)$ and $N_3 = (t_3, i_3, f_3)$ are three single valued neutrosophic numbers, *then it is concluded that* the division of N_2 on N_1 can be expressed as follows:

Suppose $N_1 \times N_2 = N_3$

$(t_1, i_1, f_1) \times (t_2, i_2, f_2) = (t_3, i_3, f_3)$

$(t_1, i_1, f_1) \times (t_2, i_2, f_2) = (t_1 t_2, i_1 + i_2 - i_1 i_2, f_1 + f_2 - f_1 f_2)$

Then $N_3/N_2 = N_1$

$i_3 = i_1 + i_2 - i_1 i_2$

$i_3 + (-i_1) = (i_1 + i_2 - i_1 i_2) + (-i_1)$

$i_3 - i_1 = i_1 + i_2 - i_1 i_2 - i_1$

$i_3 - i_1 = i_2 - i_1 i_2$

$i_2 - i_1 i_2 = i_3 - i_1$

$i_2 (-i_3 + 1) / -i_3 + 1 = i_3 - i_1 / i_1 + 1$

$i_2 = i_3 - i_1 / 1 - i_1$

$$\text{Therefore, } N_2/N_1 = (t_2/t_1, i_2 - i_1/1 - i_1, f_2 - f_1/1 - f_1) \qquad (3)$$

Definition 3: If $N_1 = (t_1, i_1, f_1)$ is a single valued neutrosophic number and A is an arbitrary positive real number, then the multiplication of N_1 and A can be expressed as follows:

$$A \times N_1 = (1 - (1 - t_1)^A, i_1^A, f_1^A) , \text{ Where } A > 0 \qquad (4)$$

Therefore, If $N_1 = (t_1, i_1, f_1)$ is a single valued neutrosophic number and A is an arbitrary positive real number,

From equation (4), Authors derived the division operation which is not presented in previous researches as following:

Therefore, the division of N_1 over A can be expressed as follows:

$$N_1 / A = (1 - (1 - t_1)^{1/A}, i_1^{1/A}, f_1^{1/A}) , \text{ Where } A > 0 \qquad (5)$$

Definition 4: If N_1 is a single valued neutrosophic number, a score function is mapped N_1 into the single crisp output as $S(N_1)$ follows:

$$S(N_1) = (3 + t_1 - 2i_1 - f_1)/4 \qquad (6)$$

3. Using the Neutrosophic Analytic Hierarchy Process Method (NAHP) for LMS Selection

In this section, an applied example would be presented of how the multi-criteria decision making problem is solved, in order to demonstrate aspects of the neutrosophic sets implementation. The LMS problem is used a case in order to study the performance of the proposed NAHP method. The working team determined the decision hierarchy as shown in Figure 1. Five alternatives are available in this case: Moodle, Sakai, Atutor, ILIAS, and Dokeos. Five main criteria are used: cost, evaluative tools, computability, support, and sustainability. The student tracking and exam pool were defined as a sub criteria of the evaluative tools. Complying with the platform and content development tools were defined as a sub criteria of compatibility. Documentation and technical were defined as a sub criteria of support.
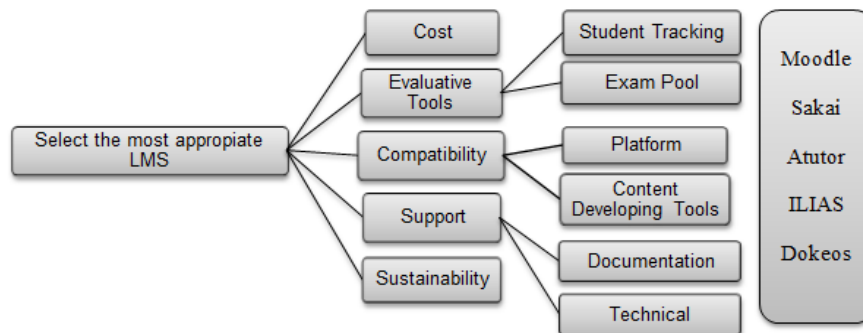

Figure 1. Decision Hierarchy Model of the LMS

Using the relative importance of the alternatives, a matrix was constructed in terms of each criterion. The importance of one element over another is expressed in relation to the element in the higher level using Saaty 9-point scale. A set of linguistic variables used by decision makers and importance weight based on neutrosophic values are as shown in Table 1.

Table 1. Linguistic variables and Importance weight based on neutrosophic values

Linguistic Term	Neutrosophic Set	Linguistic Term	Reciprocal Neutrosophic Set
Extremely Highly Preferred	(0.90, 0.10, 0.10)	Mildly Lowly Preferred	(0.10, 0.90, 0.90)
Extremely Preferred	(0.85, 0.20, 0.15)	Mildly Preferred	(0.15, 0.80, 0.85)
Very Strongly To Extremely Preferred	(0.80, 0.25, 0.20)	Mildly preferred to Very Lowly Preferred	(0.20, 0.75, 0.80)
Very Strongly Preferred	(0.75, 0.25, 0.25)	Very Lowly Preferred	(0.25, 0.75, 0.75)
Strongly Preferred	(0.70, 0.30, 0.30)	Lowly Preferred	(0.30, 0.70, 0.70)
Moderately Highly To Strongly Preferred	(0.65, 0.30, 0.35)	Moderately Lowly Preferred to Lowly Preferred	(0.35, 0.70, 0.65)
Moderately Highly Preferred	(0.60, 0.35, 0.40)	Moderately Lowly Preferred	(0.40, 0.65, 0.60)
Equally To Moderately Preferred	(0.55, 0.40, 0.45)	Moderately to Equally Preferred	(0.45, 0.60, 0.55)
Equally Preferred	(0.50, 0.50, 0.50)	Equally Preferred	(0.50, 0.50, 0.50)

Then the experts carried out a comparison, in pairs, of the first criteria versus the goal, then of the sub criteria versus the criteria, and finally of the alternatives versus each of the sub criteria. There are 12 pairwise comparison matrices in total. One was for the criteria with respect to the goal, which is shown in Table 2, and three for the sub criteria, the first of which are those for the sub criteria under evaluative tools: student tracking and exam pool; these are shown in Table 4. The other two pairwise matrices for the sub criteria under compatibility and support are not shown here.

Table 2. Pairwise Comparison Matrix with Respect to the Goal

	Cost 1	Evaluative Tools 2	Compatibility 3	Support 4	Sustainability 5	Weight
Cost 1	(0.50, 0.50, 0.50)	(0.25, 0.75, 0.75)	(0.40, 0.65, 0.60)	(0.40, 0.65, 0.60)	(0.50, 0.50, 0.50)	(0.4292, 0.5902, 0.5708)
Evaluative tools 2	(0.75, 0.25, 0.25)	(0.50, 0.50, 0.50)	(0.60, 0.35, 0.40)	(0.60, 0.35, 0.40)	(0.60, 0.35, 0.40)	(0.6382, 0.3298, 0.3618)

Compatibility 3	(0.60, 0.35, 0.40)	(0.40, 0.65, 0.60)	(0.50, 0.50, 0.50)	(0.60, 0.35, 0.40)	(0.60, 0.35, 0.40)	(0.5632, 0.4087, 0.4368)
Support 4	(0.60, 0.35, 0.40)	(0.40, 0.65, 0.60)	(0.40, 0.65, 0.60)	(0.50, 0.50, 0.50)	(0.50, 0.50, 0.50)	(0.5011, 0.5027, 0.4989)
Sustainability 5	(0.50, 0.50, 0.50)	(0.40, 0.65, 0.60)	(0.40, 0.65, 0.60)	(0.50, 0.50, 0.50)	(0.50, 0.50, 0.50)	(0.4779, 0.5404, 0.5221)

Checking the consistency in step four of each pairwise comparison neutrosophic preference relation is an important point. In the conventional AHP, Saaty provided a consistency ratio CR to measure the degree of consistency for a multiplicative preference relation as to be less than 0.1. From [9, 10], it is concluded that in our work there are two methods for checking consistency:

First, by converting the neutrosophic reference relations into their corresponding crisp preference relations, and then using the Saaty method to check the consistency ratio as to be less than 0.1.

Second, by modification applied to the method used by Zeshui. X. and Liao. H. [17] to suit neutrosophic method. Authors developed this algorithm is to construct a perfect consistent neutrosophic preference relation where (T'xk , I'xk, F'xk) is an acceptable consistent neutrosophic reference relation as follows:

Step 1: For $k > x + 1$, let $N_{xk} = (T'_{xk}, I'_{xk}, F'_{xk})$, where $y = x+1$

$$T'_{xk} = \frac{\sqrt[k-x-1]{T_{xy} * T_{yk} * T_{x\,k-1} * T_{k-1\,k}}}{\sqrt[k-x-1]{T_{xy} * T_{yk} * T_{i\,k-1} * T_{k-1\,k}} + \sqrt[k-x-1]{(1-T_{xy}) * (1-T_{yk}) * (1-T_{x\,k-1}) * (1-T_{k-1\,k})}} \qquad (7)$$

$$I'_{xk} = \frac{\sqrt[k-x-1]{I_{xy} * I_{yk} * I_{x\,k-1} * I_{k-1\,k}}}{\sqrt[k-x-1]{I_{xy} * I_{yk} * I_{x\,k-1} * I_{k-1\,k}} + \sqrt[k-x-1]{(1-I_{xy}) * (1-I_{yk}) * (1-I_{x\,k-1}) * (1-I_{k-1\,k})}} \qquad (8)$$

$$F'_{xk} = \frac{\sqrt[k-x-1]{T_{xy} * T_{yk} * T_{x\,k-1} * T_{k-1\,k}}}{\sqrt[k-x-1]{T_{xy} * T_{yk} * T_{x\,k-1} * T_{k-1\,k}} + \sqrt[k-x-1]{(1-T_{xy}) * (1-T_{yk}) * (1-T_{x\,k-1}) * (1-T_{k-1\,k})}} \qquad (9)$$

Step 2: For $k = x + 1$, let $N_{xk} = (T_{xk}, I_{xk}, F_{xk})$, where $y = x+1$

Step 3: For $k < x$, let $N_{xk} = (F'_{xk}, 1 - I'_{xk}, T'_{xk})$, where $y = x+1$

Consistency Ratio (CR) $= \frac{1}{2(n-1)(n-2)} \sum_{x=1}^{n} \cdot \sum_{k=1}^{n} \cdot (|T'_{xk} - T_{xk}| + |I'_{xk} - I_{xk}| + |F'_{xk} - F_{xk}|)$ (10)

should be less than 0.1.

According to (7), (8), (9) and (10), the consistency of the neutrosophic pairwise comparison matrix with respect to the goal is constructed as shown in Table 3.

For example, to calculate $T_{25} =$

$$\frac{\sqrt[2]{T_{23} * T_{35} * T_{24} * T_{45}}}{\sqrt[2]{T_{23} * T_{35} * T_{24} * T_{45}} + \sqrt[2]{(1-T_{23}) * (1-T_{35}) * (1-T_{24}) * (1-T_{45})}} = \frac{\sqrt[2]{0.60 * 0.60 * 0.60 * 0.50}}{\sqrt[2]{0.60 * 0.60 * 0.60 * 0.50} + \sqrt[2]{0.40 * 0.40 * 0.40 * 0.50}}$$
$$= 0.6475$$

Then CR is calculated as follows

Consistency Ratio (CR) $= \frac{1}{2(5-1)(5-2)} \sum_{x=1}^{n} \cdot \sum_{k=1}^{n} \cdot (|12.5 - 12.5| + |12.5 - 12.5| + |12.5 - 12.5|) = 0$ which is less than 0.1

Table 3. Consistency Pairwise Comparison Matrix with Respect to the Goal

	Cost 1	Evaluative Tools 2	Compatibility 3	Support 4	Sustainability 5
Cost 1	11 (0.50, 0.50, 0.50)	12 (0.25, 0.75, 0.75)	13 (0.4142, 0.5597, 0.5858)	14 (0.4142, 0.5597, 0.5858)	15 (0.4095, 0.5905, 0.5905)
Evaluative Tools 2	21 (0.75, 0.25, 0.25)	22 (0.50, 0.50, 0.50)	23 (0.60, 0.35, 0.40)	24 (0.60, 0.35, 0.40)	25 (0.6475, 0.2832, 0.3525)
Compatibility 3	31 (0.5858, 0.4403, 0.4142)	32 (0.40, 0.65, 0.60)	33 (0.50, 0.50, 0.50)	34 (0.60, 0.35, 0.40)	35 (0.5505, 0.4232, 0.4495)
Support 4	41 (0.5858, 0.4403, 0.4142)	42 (0.40, 0.65, 0.60)	43 (0.40, 0.65, 0.60)	44 (0.50, 0.50, 0.50)	45 (0.50, 0.50, 0.50)
Sustainability 5	51 (0.5905, 0.4095, 0.4095)	52 (0.3525, 0.7168, 0.6475)	53 (0.4495, 0.5768, 0.5505)	54 (0.50, 0.50, 0.50)	55 (0.50, 0.50, 0.50)

Table 4. Pairwise Comparison Matrix for the Sub Criteria Under Evaluative Tools

|	Exam Pool	Student Tracking	Weight
Exam Pool	(0.50,0.50,0.50)	(0.75, 0.25, 0.25)	(0.8309 0.1691, 0.1691)
Student Tracking	(0.25,0.75,0.75)	(0.50,0.50,0.50)	(0.4929 0.5071, 0.5071)

4. Results

The final objective of this study was to present a neutrosophic multi-criteria decision making method to select the most suitable LMS product according to the defined criteria. The results generated by the proposed method have three components of truthfulness, indeterminacy, and falsehood, unlike the case of fuzzy sets which represents the true membership value only, and which has no solution when decision makers are hesitant to define the membership. Intuitionistic fuzzy sets represent the true membership and false membership, but cannot handle indeterminacy, which expresses the percentage of unknown parameters. On the contrary, the neutrosophic sets deal with vagueness when the information is naturally graded, and with imprecision when the available information is not specified, and with ambiguity when information is unclear and inconsistent and when information obtainable conflicts with information existing in the real world.

The overall weight of the criteria and the sub criteria based on the neutrosophic numbers can be seen in Table 5. There are eight comparison matrices for the five alternatives with respect to all the criteria and the

sub criteria connected to the alternatives which are not shown here. Figure 2 shows the column graph of the results from the scale based on the judgments.

Table 5. The Overall Priority of the Criteria and the Sub Criteria

| Criteria	Criteria Weight (CW)	Sub Criteria	Sub Criteria Weight (SCW)	Overall Weight= CW x SCW
Cost	(0.4292, 0.5902, 0.5708)			(0.4292, 0.5902, 0.5708)
Evaluative Tools	(0.6382, 0.3298, 0.3618)	Student Tracking	(0.4929, 0.5071, 0.5071)	(0.3146, 0.6697, 0.6854)
		Exam Pool	(0.8309 0.1691, 0.1691)	(0.5303, 0.4331, 0.4697)
Compatibility	(0.5632, 0.4087, 0.4368)	Platform	(0.5991, 0.4355, 0.4009)	(0.3374, 0.6662, 0.6626)
		Content Developing Tools	(0.7328 0.2345, 0.2672)	(0.4127, 0.5474, 0.5873)
Support	(0.5011, 0.5027, 0.4989)	Documentation	(0.5645 0.4697, 0.4355)	(0.2829, 0.7363, 0.7171)
		Technical	(0.7655 0.2017, 0.2345)	(0.3836, 0.6030, 0.6164)
Sustainability	(0.4779, 0.5404, 0.5221)			(0.4779, 0.5404, 0.5221)
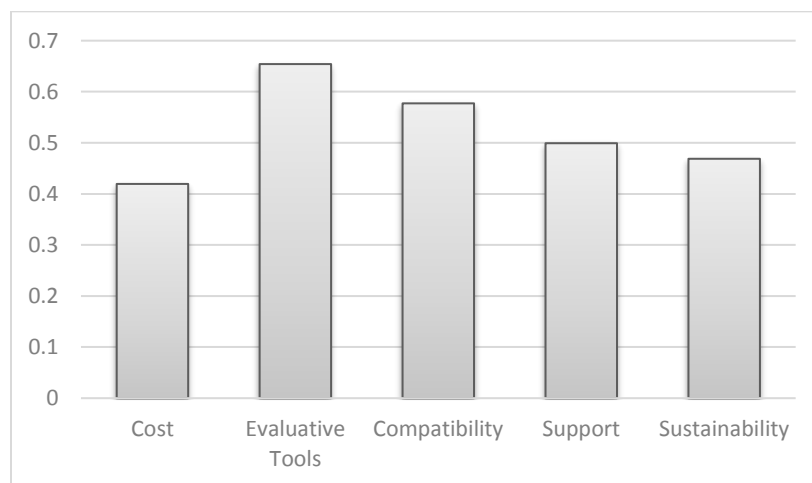
Figure 2. Weight Percentages of the Neutrosophic Scale Based on Judgements of the Criteria

According to Table 6 and Figure 3, Moodle is the most suitable choice for the project. All readers should be aware that the methodology used in this paper does not evaluate a software product. The results show that using the neutrosophic sets for an LMS selection is a better option than the fuzzy and intuitionistic fuzzy logic, as it simulates the human thinking, and because the fuzzy logic cannot express the falsehood membership, and the intuitionistic fuzzy logic is not able to handle indeterminacy of information. Also, is it shown how NAHP can be used when making a decision. It should be noted that the results can differ when a change of priorities and objectives is done, and if priorities change, scores will change. In conclusion, according to the given priorities shown in the criteria and sub criteria, Moodle is the best choice.

Table 6. The Overall Score of Different Alternatives

Alternatives	Neutrosophic Set	Deneutrosophied Number	Ranking
Moodle	(0.8838, 0.0949, 0.1162)	0.8945	1
Atutor	(0.8709, 0.1120, 0.1291)	0.8795	2
Dokeos	(0.8315, 0.1655, 0.1685)	0.8330	3
Sakai	(0.8147, 0.1895, 0.1853)	0.8126	4
ILIAS	(0.8020, 0.2096, 0.1980)	0.7962	5
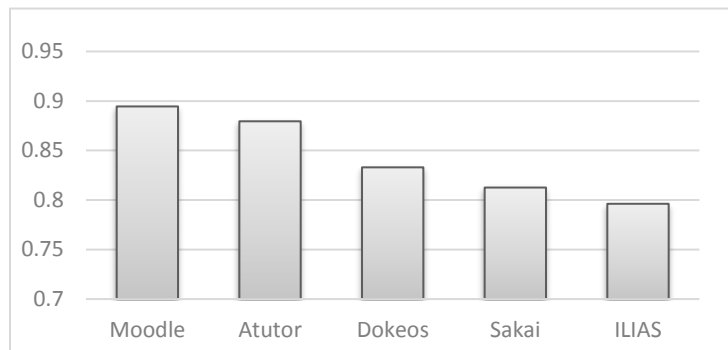
Figure 3. Weight Percentages of the Neutrosophic Scale Based the Alternatives

5. Conclusion

Fuzzy sets offer a poor representation of uncertain data, as it expresses the membership in a crisp value between 0 and 1. The membership degree of a given element in a fuzzy set does not express the corresponding degree of non-membership as the complement to 1. Intuitionistic fuzzy sets are suitable in simulating the impreciseness of human understanding in decision making. The decision making process depends not only on information that is either true and false, but it also depends on indeterminate information, which is represented by an ignorance value between truth and falsehood. For example, if an expert is asked about his opinion on a certain statement, he might say that the possibilities are as follows: first the statement is true, second the statement is false, and third that it represents an indeterminacy, and the value would be 0.6, 0.3 and 0.5 respectively. This can be appropriately handled by neutrosophic logic, which have the truthfulness, indeterminacy and falsehood membership functions independent of each other.

This paper presents a neutrosophic multi criteria decision making method as a novel approach, and it is applied to the case of selecting a learning management system according to the decision makers' priorities and preferences. Using the NAHP provides reliable results due to the fact that uncertain preferences can be expressed as neutrosophic sets. An illustrative example was used to illustrate the application of the proposed method in making a choice about the best fit LMS. According to the determined priorities,

Moodle LMS proved to be the most appropriate one that met the defined criteria, after that comes Atutor, Dokeos, Sakai, Ilias orderly. The developed NAHP method can be used for different types of MCDM problems.

The use of the NAHP as a multi-criteria decision making method, for the selection of the most appropriate LMS, using given priorities and criteria, was presented. NAHP offers reliable results when a collaboration takes place between decision makers and experts, and a good methodology is adopted. The inconsistency checking during the pairwise comparisons makes the NAHP reliable as a decision making method, even for people who are less experienced in taking decisions. The results of the study cannot be generalized, due to the face that the NAHP cannot evaluate products by itself.

6. Future Work

Further work interest is dealing with system quality evaluation of LMSs described by uncertain terms using neutrosophic logic approach. Neutrosophic Logic is a new approach for evaluating the system quality attributes of various systems that can adapt variations and changes.

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References

[1] Nouran Radwan, M. Badr Senousy, and M. Alaa El Din, "Current trends and challenges of developing and evaluating learning management systems." International Journal of e-Education, e-Business, e-Management and e-Learning 4.5, pp.361-375, 2014.
[2] Norkhushaini Bt. Awang, and Mohamad Yusof B. Darus, "Evaluation of an open source learning management system: claroline." Procedia-Social and Behavioral Sciences 67, pp.416-426, 2012.
[3] Chih-Hung Chung,, Laura A. Pasquini, and Chang E. Koh, "Web-based learning management system considerations for higher education." Learning and Performance Quarterly 1.4, pp.24-37, 2013.
[4] Hamed Fawareh, "Elearning management systems general framework." World Academy of Science, Engineering and Technology, 7 (9), pp.1221-1225, 2013.
[5] Anil Aggarwal, Veena Adlakha, and Terry Ross, "A Hybrid approach for selecting a course management system: A case study." Journal of Information Technology Education 11, pp. 283-300, 2012.
[6] Don McIntosh, "Vendors of learning management and e-learning products." PhD, Trimeritus eLearning Solutions Inc., pp.88-96, 2014.
[7] Joel Samson Mtebe, and Roope Raisamo, "A model for assessing Learning Management System Success in higher education in sub-Saharan countries." The Electronic Journal of Information Systems in Developing Countries 61, pp.1-17, 2014.
[8] Nadire Cavus, "The evaluation of Learning Management Systems using an artificial intelligence fuzzy logic algorithm." Advances in Engineering Software 41.2, pp.248-254, 2010.
[9] Ridvan Sahin, and Muhammed Yigider. "A Multi-criteria neutrosophic group decision making method based TOPSIS for supplier selection." arXiv preprint arXiv:1412.5077 ,2014.
[10] Jun Ye, "An extended TOPSIS method for multiple attribute group decision making based on single valued neutrosophic linguistic numbers." Journal of Intelligent & Fuzzy Systems 28.1, pp.247-255, 2015.

[11] Martin Aruldoss, T. Miranda Lakshmi, and V. Prasanna Venkatesan, "A survey on multi criteria decision making methods and its applications." American Journal of Information Systems 1.1, pp.31-43, 2013.

[12] Mark Velasquez, and Patrick T. Hester, "An analysis of multi-criteria decision making methods." International Journal of Operations Research 10.2, pp.56-66, 2013.

[13] Nadire Cavus, "Selecting a learning management system (LMS) in developing countries: instructors' evaluation." Interactive Learning Environments 21.5, pp.419-437, 2013.

[14] Bojan Srdevic, Matija Pipan, Zorica Srdevic, Tanja Arh, "AHP supported evaluation of LMS quality." International workshop on the interplay between user experience (UX) Evaluation and system development (I-UxSED 2012). Vol. 52, pp.52-57, 2012.

[15] Thomas Saaty, "An exposition of the AHP in reply to the paper "remarks on the analytic hierarchy process"." Management science 36.3, pp.259-268, 1990.

[16] Zeshui Xu, and Huchang Liao, "Intuitionistic fuzzy analytic hierarchy process." IEEE Transactions on Fuzzy Systems 22.4, pp.749-761, 2014.

[17] Ali Hakan Isik, Murat Ince, and Tuncay Yigit, "A Fuzzy AHP Approach to Select Learning Management System." International Journal of Computer Theory and Engineering 7.6, pp.499-502, 2015.

[18] Chun-Kit Kwong, and H. Bai, "Determining the importance weights for the customer requirements in QFD using a fuzzy AHP with an extent analysis approach." Iie Transactions 35.7, pp.619-626,2003.

[19] Osman Kulak, and Cengiz Kahraman,"Fuzzy multi-attribute selection among transportation companies using axiomatic design and analytic hierarchy process." Information Sciences 170.2, pp.191-210, 2005.

[20] Krassimir Atanssov, "Intuitionistic fuzzy sets." Fuzzy sets and Systems 20.1, pp.87-96, 1986.

[21] Glad Deschrijver, and Etienne E. Kerre, "On the composition of intuitionistic fuzzy relations." Fuzzy Sets and Systems 136.3, pp.333-361, 2003.

[22] Zeshui Xu, "Intuitionistic preference relations and their application in group decision making." Information sciences 177.11, pp.2363-2379, 2007.

[23] Zeshui Xu, "Intuitionistic fuzzy multiattribute decision making: an interactive method." IEEE Transactions on Fuzzy Systems 20.3, pp.514-525, 2012.

[24] Florentine Smarandache, "Neutrosophy Neutrosophic Probability. Set, and Logic". Amer Res Press Rehoboth, USA, pp.12-20, 1998.

[25] Abdul Quaiyum Ansari, Ranjit Biswas, and Swati Aggarwal, "Extension to fuzzy logic representation: Moving towards neutrosophic logic -A new laboratory rat." Fuzzy Systems (FUZZ), 2013 IEEE International Conference on. IEEE, 2013.

[26] Supriya Raheja, and Reena Dhadich, "Many-Valued Logics for Modeling Vagueness." International Journal of Computer Applications 61.7, pp.35-39, 2013.

[27] Swati Aggarwal, Ranjit Biswas, and A. Q. Ansari, "Neutrosophic modeling and control." Computer and Communication Technology (ICCCT), 2010 International Conference on. IEEE, pp.718-723, 2010.

[28] Matija Pipan, Tanja Arh, and B. Blažič, "The evaluation cycle management-method applied to the evaluation of learning management systems." Integrating usability engineering for designing the web experience: methodologies and principles, pp.58-80, 2010.

[29] Nouran Radwan, "An Adaptive Learning Management System Based on Learner's Learning Style." International Arab Journal of e-Technology 3.4, pp.7-20, 2014.

[30] A.Q. Ansari, Ranjit Biswas, and Swati Aggarwal, "Proposal for applicability of neutrosophic set theory in medical AI." International Journal of Computer Applications 27.5, pp.5-11, 2011.

[31] Haibin Wang, Florentin Smarandache, Yan-Qing Zhang, Rajshekhar Sunderraman, "Interval Neutrosophic Sets and Logic: Theory and Applications in Computing: Theory and Applications in Computing". Vol. 5. Infinite Study, pp.1-38, 2005.

[32] Jun Ye, "A multicriteria decision-making method using aggregation operators for simplified neutrosophic sets." Journal of Intelligent & Fuzzy Systems 26.5, pp.2459-2466, 2014.

[33] Daniel Y. Shee, and Yi-Shun Wang. "Multi-criteria evaluation of the web-based e-learning system: A methodology based on learner satisfaction and its applications." Computers & Education 50.3, pp. 894-905, 2008.