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One MCDM Approach to Learning Management Systems Evaluation

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Abstract: *In the paper are presented and also illustrated on a practical example possibilities of applying one MCDM approach to evaluation of the Learning Management Systems (LMSs) as an important tool in achieving more efficient educational processes. This study proposes a Fuzzy Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) approach to support evaluation of LMSs under fuzzy environment. The proposed approach enables decision makers to identify the alternative, which is closest to the ideal solution and provide more accurate and effective decision support tool, also by implementation of the fuzzy set theory within the TOPSIS process the problems of vagueness and ambiguity are solved.*

Keywords: *Learning Management System; MCDM approach; Fuzzy TOPSIS method*

1. INTRODUCTION

As technological progress is increasingly more intense, it is become vital for education institutions to take advantage of them to enhance teaching and learning processes. The LMS is one of a powerful software-based tools that will enable progress of education processes. LMS is a software-based platform for the administration, documentation, tracking, reporting and delivery of educational processes [1].

According to Coates, James & Baldwin [2] LMS provides tools for course administration and pedagogical functions of differing sophistication and potential:

- asynchronous and synchronous communication (announcement areas, e-mail, chat, list servers, instant messaging and discussion forums);
- content development and delivery (learning resources, development of learning object repositories and links to internet resources);
- formative and summative assessment (submission, multiple choice testing, collaborative work and feedback) and class and user management (registering, enrolling, displaying timetables, managing student activities and electronic office hours).

The main benefits of using LMS are: reducing learning and development costs, reducing learning time, centralizing learning resources, tracking of learner`s and teacher`s progress, increasing knowledge retention, enables flexible and collaborative learning, creating courses easily using simple editing settings, easy integration with other systems, enables analytics and reporting features, also it increases students' engagement and brings a new dynamics in academic work and the organization of teaching, etc.

LMS is a part of an important culture shift taking place in teaching and learning in higher education [2].

The list of LMS users includes much more than just educational institutions: Traditional educational institutions such as schools, universities or colleges, businesses of all types and sizes, non-government and non-profits organizations, government agencies and local governments and online and eLearning based educational institutions. They are using LMS for: students' education in eLearning form, employee training, employee orientation and professional development, knowledge retention, etc.

The LMS handles the management and delivery of eLearning courses, also it is a powerful tool for transforming traditional educational processes into advanced forms such as eLearning or distance learning.

The quality of LMS software application is the one that obtains: diverse content options, course creation tools, learning paths, education processes assessments, interactive discussions and peer support, reporting of the education processes results.

There are numerous studies which researche the perspectives and benefits of using the LMS within educational processes [3], [4], [5], [6], [7].

There are over 700 solutions of the LMS, each offering something different than the next one.

Selecting the best LMS for some institution`s unique learning needs isn't an easy task.

When evaluating the LMSs, it is not enough to consider only the technical characteristics of software applications that support the LMS concept, but it is necessary to take into account all the characteristics that determine the quality of these software applications.

The people involved in the evaluation process must asses to what extent the considered LMS meet customer requirements in terms of pricing, functionality, usability in different education systems, opportunities that they offer for evaluating of learning-teaching processes, and to asses whether that software provide appropriate support to the users which will enable them to easily install, use and maintenance the software application.

Due to the complexity, this process must be carried out exclusively by an expert team that will be made by experts from the education field, as well as IT experts, so that all aspects of assessment will be covered in an adequate manner and rational results will be secured. Also, this process requires the application of complex decision-making methods.

As we can conclude from the above, selection of the appropriate LMS is a complex process that requires a multi-aspect estimation, so a rational evaluation and ranking of LMSs requires the application of MCDM techniques.

In literature, there are several proposed approaches to LMSs evaluation, many of them are based on the use of MCDM techniques. Işık, Ince & Yigit [8] proposed Fuzzy Analytic Hierarchy Process (AHP) methodology for the selection of the most appropriate LMS. In the study [9], authors used Analytic Network Process in order to evaluate and recommend the LMS. Radwan, Senousy, Riad & El Din [10] introduced the new expert system for LMS evaluation based on neutrosophic sets. Cavus [11] evaluated the LMS alternatives using an artificial intelligence fuzzy logic algorithm.

Rational assessment of LMSs according to different criteria is possible by using Fuzzy TOPSIS method. This method will enable identification of the alternative, which is closest to the ideal solution, according the obtained closeness coefficient. Also, this approach will provide a more accurate and effective decision support tool. Also by implementation of the fuzzy set theory within the TOPSIS process the problems of vagueness and ambiguity are solved.

2. METHODOLOGY

The LMSs evaluation process, in this paper, will be conduct by application the Fuzzy TOPSIS method. TOPSIS method was first introduced by Hwang & Yoon [12], it is widely used MCDM technique for ranking alternatives that are estimated in the system of different qualitative and quantitative criteria. The TOPSIS method rankes alternatives according to their distance from ideal solution. Let $\tilde{X} = [\tilde{x}_{ij}]_{m \times n}$ be the decision matrix of considered problem with n alternatives $(A_1, A_2 \dots, A_n)$, and m criteria $(C_1, C_2, \dots, C_m)$.

$$\tilde{X} = \begin{matrix} & C_1 & C_2 & \cdots & C_m \\ A_1 & \tilde{x}_{11} & \tilde{x}_{12} & \cdots & \tilde{x}_{1m} \\ A_2 & \tilde{x}_{21} & \tilde{x}_{22} & \cdots & \tilde{x}_{2m} \\ \vdots & \vdots & \vdots & \cdots & \vdots \\ A_n & \tilde{x}_{n1} & \tilde{x}_{n2} & \cdots & \tilde{x}_{nm} \end{matrix} \tag{1}$$

Where $\tilde{x}_{ij}$ represents the preferences of the alternative A_i over the alternative A_j, estimated by decision makers.

Since decision makers are not capable to accurately express their subjective preferences, these are characterized by uncertainty and ambiguity. In order to handle with vagueness it is proposed the expansion of TOPSIS method by Fuzzy logic, or the application of Fuzzy TOPSIS method [13].

In order to deal with the vagueness of decision makers' subjective preferences, preferential relationships will be expressed by linguistic expressions (Very Poor, Poor, Fair…) that will be further represented by triangular fuzzy numbers $(x_{ij}^l, x_{ij}^m, x_{ij}^u)$, where are: x_{ij}^l - a pessimistic estimate, x_{ij}^m – a most probable value, x_{ij}^u - a optimistic estimate (Fig. 1).

The triangular fuzzy number belongs to closed interval $[0,1]$.

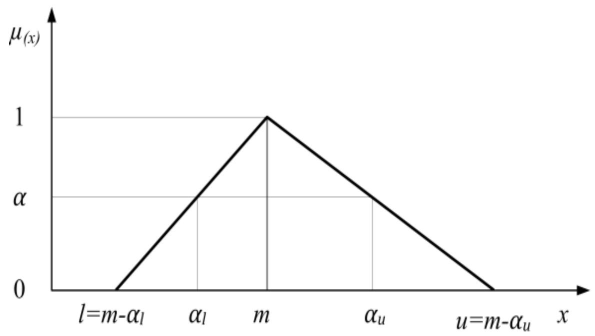

Figure 1. *The triangular fuzzy number*

Fuzzification of the linguistic expressions will be performed using the most frequently used scale in the literature, which is shown in Table 1 and Fig. 2.

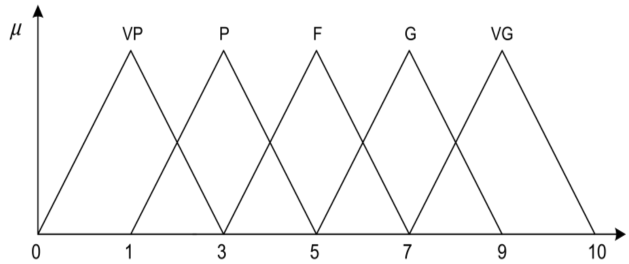

Figure 2. *Fuzzification of linguistic scale for alternative performance*

Table 1. *Fuzzified scales*

Linguistic Scale	Triangular Fuzzy Scale

Very poor (VP)	(0,1,3)
Poor (P)	(1,3,5)
Fair (F)	(3,5,7)
Good (G)	(5,7,9)
Very good (VG)	(7,9,10)

Normalization of the decision matrix ($\tilde{R} = [\tilde{r}_{ij}]_{m\times n}$) will be executed by the transformation:

$$\tilde{r}_{ij} = \left(\frac{x_{ij}^l}{x_{ij}^{u+}}, \frac{x_{ij}^m}{x_{ij}^{u+}}, \frac{x_{ij}^u}{x_{ij}^{u+}}\right) = (r_{ij}^l, r_{ij}^m, r_{ij}^u) \quad (2)$$

Where the x_{ij}^{u+} is $max\ (x_{ij}^u)$.

The next step is to obtain a weighted and normalized matrix ($\tilde{V} = [\tilde{v}_{ij}]_{m\times n}$) by multiplying the elements of the normalized matrix ($\tilde{r}_{ij}$) with the criteria weight (w_j).

$$\tilde{v}_{ij} = \tilde{r}_{ij} \otimes w_j = (v_{ij}^l, v_{ij}^m, v_{ij}^u) \quad (3)$$

The ideal and negative ideal alternatives are determined as follows:
The positive ideal solution (PIS):

$$A^+ = (v_{ij}^{l\ +}, v_{ij}^{m+}, v_{ij}^{u\ +}) \quad (4)$$

The negative ideal solution (NIS):

$$A^- = (v_{ij}^{l\ -}, v_{ij}^{m-}, v_{ij}^{u\ -}) \quad (5)$$

The final ranking of alternatives is determined on the base of the relative closeness to the ideal solution:

$$CC_i = \frac{d_i^-}{d_i^+ + d_i^-} \quad (6)$$

Where d_i^+ is distance of the alternative from FPIS.

$$d_i^+ = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_j^+), i = 1,2,\ldots,n; j = 1,2,\ldots,m \quad (7)$$

And d_i^- distance of the alternative from FNIS.

$$d_i^- = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_j^-), i = 1,2,\ldots,n; j = 1,2,\ldots,m \quad (8)$$

3. THE LMSs EVALUATION BY USING THE FUZZY TOPSIS METHOD

In order to illustrate the possibilities of implementing the proposed MCDM approach to evaluating LMS as an important tool in providing more effective education processes, 7 alternatives (LMS software applications) are generated (Table 2). Those LMS software applications are mostly used in higher education practice, they also correspond in their characteristics to the requirements of educational processes that are realized in our conditions.

Table 2. *Generated alternatives*

Alternative	Producer
Moodle	by Moodle
Geenio	by Geenio
TalentLMS	by Epignosis
Invanto Platform	by Invanto
LearningStone	By LearningStone
EduBrite	by EduBrite Systems
MindScroll LMS	by MindScroll

According to the available information about the alternatives, decision makers, involved in the LMS evaluation process, will assess those alternatives. Evaluation of the alternatives will be performed according to the Fuzzy TOPSIS methodology presented in the previous section.

The generated alternatives will be evaluated in a system of 5 qualitative and quantitative criteria as the key aspects of the quality of the LMS. According to the decision makers` opinions, the following criteria were selected: Functionality, Price, User Support, Usability and Evaluation Tools. By incorporating these criteria into the MCDM process, all aspects relevant to solving the LMSs evaluation problem were considered.

Functionality: Software functionality relates to its ability to, through its function, successfully respond to users' requirements. In the context of the LMS software application, this criterion considers whether the software provides the necessary functions and modules for supporting all teaching-learning processes such as: Student Portal, Training Companies, Skills Tracking, Mobile Learning, Asynchronous Learning, Video Conferencing, Skills Tracking, Lesson Plan Management, Test Building, Integration with other systems, Analytics and reporting features, Success Manager.

Price: When considering LMS price, should be included: price of license, upgrading price, implementation and training cost, price of optional functions and modules, and the cost of engaging additional hardware potentials.

User Support: Producers of LMSs softwares applications offers user support in the form of Community sites, blogs, training programs, consulting, guides for using...

Usability: Usability of the LMS software application represents the degree to which the software can be used by specified consumers to fulfill effectively the users` requirements in a quantified context of use.

Evaluation Tools: This criterion considers whether the LMS provides support for evaluation processes, such support for multiple types of questions and a variety of test types. Extensive reporting on test results.

In the LMSs evaluation process is involved a decision-making team. The decision-making team includes two education experts and an IT expert. Education experts have the task of assessing the effects of applying of the considered LMS on the quality of learning-teaching processes, while the IT expert is in charge of assessing the technical characteristics of these LMS software applications. This way, all the aspects of the assessment are covered, so the final results will be more rational.

The criteria involved in the decision-making process are of different importance, so first they must be assigned different relative weight. Decision makers are asked to estimate the criteria importance by using language expressions: 'Very poor', 'Poor', 'Fair', 'Good' and 'Very good'. Those expressions are further fuzzified according to Table 1. By aggregation of the decision makers` opinions, criteria relative weight are obtained. Those results are shown in Table 3.

As we can conclude from the results obtained the most important criterion for this evaluation process is Functionality. This criterion will have the greatest impact on the LMSs softwares selection. Also the smallest feature has the criterion Evaluation Tools, however, this criterion is not insignificant and must be included in the evaluation process.

The relative criteria weight obtained in this step will be further used in the TOPSIS process for construction of the weighted normalized decision matrix.

Table 3. *The criteria fuzzy relative weight*

Criterion	Decision maker 1	Decision maker 1	Decision maker 1	Aggregate value
Functionality	VG	G	G	(5.59, 7.61, 9.32)
Price	P	G	F	(2.47, 4.72, 6.8)
User Support	F	F	G	(3.56, 5.59, 7.61)
Usability	G	F	VG	(4.72, 6.8, 8.57)
Evaluation Tools	F	P	F	(2.08, 4.22, 6,26)

In the same way, the evaluation of the alternatives, according to the considered criteria, was done. Aggregate decision-making matrix for the evaluation of the considered LMSs is given in Table 4.

Creating of the decision matrix in a fuzzy form represents the initial point of the Fuzzy TOPSIS process, which is represented and applied in this paper.

Table 4. *Fuzzy decision matrix for the LMSs evaluation*

	Functionality	Price	User Support	Usability	Evaluation Tools
Moodle	(6.26,8.28,9.65)	(4.22,6.26,8.28)	(4.22,6.26,8.28)	(6.26,8.28,9.65)	(2.92,5.28,7.4)
Geenio	(4.22,6.26,8.28)	(3.56,5.59,7.61)	(6.26,8.28,9.65)	(2.08,4.22,6.26)	(3.56,5.59,7.61)
TalentLMS	(5.59,7.61,9.32)	(5.59,7.61,9.32)	(5.59,7.61,9.32)	(5.28,7.40,8.88)	(5.28,7.40,8.88)
Invanto Platform	(0,1.44,3.56)	(7,9,10)	(2.08,4.22,6.26)	(1.44,3.56,5.59)	(2.47,4.72,6.8)
LearningStone	(2.08,4.22,6.26)	(0,1.44,3.56)	(2.08,4.22,6.26)	(1.44,3.56,5.59)	(4.22,6.26,8.28)
EduBrite	(0,2.47,4.72)	(0,2.08,4.22)	(5.59,7.61,9.32)	(3.56,5.59,7.61)	(3.56,5.59,7.61)
MindScroll LMS	(4.22,6.26,8.28)	(3.56,5.59,7.61)	(4.22,6.26,8.28)	(5.59,7.61,9.32)	(4.72,6.80,8.57)

After that the normalized decision matrix is determined with the help of transformation formula (2). The normalized decision matrix is presented in Table 5.

Table 5. *Normalized decision matrix*

	Functionality	Price	User support	Usability	Evaluation Tools
Moodle	(0.63,0.83,0.97)	(0.42,0.63.0.83)	(0.42,0.63,0.83)	(0.63,0.83,0.97)	(0.29,0.53,0.74)
Geenio	(0.42,0.63,0.83)	(0.36,0.56,0.76)	(0.63,0.83,0.97)	(0.21,0.42,0.63)	(0.36,0.56,0.76)
TalentLMS	(0.56,0.76,0.93)	(0.56,0.76,0.93)	(0.56,0.76,0.93)	(0.53,0.74,0.89)	(0.53,0.74,0.89)
Invanto Platform	(0,0.14,0.36)	(0.7,0.9,1))	(0.21,0.42,0.63)	(0.14,0.36,0.56)	(0.25,0.47,0.68)
LearningStone	(0.21,0.42,0.63)	(0,0.14,0.36)	(0.21,0.42,0.63)	(0.14,0.36,0.56)	(0.42,0.63,0.83)
EduBrite	(0,0.25,0.47)	(0,0.21,0.42)	(0.56,0.76,0.93)	(0.36,0.56,0.76)	(0.36,0.56,0.76)
MindScrollLMS	(0.42,0.63,0.83)	(0.36,0.56,0.76)	(0.42,0.63.0.83)	(0.56,0.76,0.93)	(0.47,0.68,0.86)

According to the equation (3), the weighted matrix is obtained by multiplying the elements of the normalized matrix shown in Table 5, with the criteria relative weight given in Table 1.

The weighted normalized decision matrix is presented in Table 6.

Table 6. *Weighted normalized decision matrix*

	Functionality	Price	User support	Usability	Evaluation Tools
Moodle	(3.5,6.3,9)	(1.04,2.95,5.63)	(1.5,3.5,6.3)	(2.95,5.63,8.28)	(0.61,2.23,4.63)
Geenio	(2.36,4.76,7.72)	(0.88,2.64,5.18)	(2.23,4.63,7.35)	(0.98,2.87,5.36)	(0.74,2.36,4.76)
TalentLMS	(3.13,5.79,8.69)	(1.38,3.59,6.34)	(1.99,4.26,7.1)	(2.49,5.03,7.61)	(1.1,3.12,5.56)
Invanto Platform	(0,1.1,3.32)	(1.73,4.25,6.8)	(0.74,2.36,4.76)	(0.68,2.42,4.8)	(0.51,1.99,4.26)
LearningStone	(1.16,3.21,5.83)	(0,0.68,2.42)	(0.74,2.36,4.76)	(0.68,2.42,4.8)	(0.88,2.64,5.18)
EduBrite	(0,1.88,4.4)	(0,0.98,2.87)	(1.99,4.26,7.1)	(1.68,3.81,6.53)	(0.74,2.36,4.76)
MindScroll LMS	(2.36,4.76,7.72)	(0.88,2.64,5.18)	(1.5,3.5,6.3)	(2.64,5.18,7.99)	(0.98,2.87,5.36)

The next step implies determining the PIS and the NIS. As $\tilde{v}_{ij}$ is characterized by triangular fuzzy number $(v_{ij}^{l}, v_{ij}^{m}, v_{ij}^{u}) \in [0,1]$ the PIS and NIS are determined as:

$$A^{+} = (1,1,1) \quad (9)$$

$$A^{-} = (0,0,0) \quad (10)$$

The distances from the PIS (d_i^{+}) and NIS (d_i^{-}) for each alternative are calculated using formulas (7) and (8). The fuzzy relative closeness (CC_i) are also determined, with the help of formula (6).

Those results are presented in Table 7.

Table 7. *The final range of the alternatives*

Alternative	d_i^{+}	d_i^{-}	Relative closeness
Moodle	25.956	23.639	0.477
Geenio	28.496	20.636	0.420
TalentLMS	24.983	24.685	0.497
Invanto Platform	32.927	15.706	0.323
LearningStone	33.476	14.971	0.309
EduBrite	31.922	16.991	0.347
MindScroll LMS	27.069	22.316	0.452

According to non-fuzzy relative closeness coefficient obtained in previous process, the final rang of the considered alternatives are determined. As we can see from conducted TOPSIS process, alternative Talent LMS is closest to the ideal solution, so that is the alternative with the best performances according to the considered criteria. The final rang is as follow:

Table 8. *Alternative rank*

Alternative	Rank
Moodle	2
Geenio	4
TalentLMS	1
Invanto Platform	6
LearningStone	7
EduBrite	5
MindScroll LMS	3

4. CONCLUSION

The paper theoretical background and practical example indicate to the possibilities of using the MCDM approach, based on Fuzzy TOPSIS methodology, for the evaluation of LMS software applications.

The proposed methodology enables decision makers to identify the alternative which is closest to the ideal solution according to different criteria that are the key aspects of LMS software application quality. On the other hand, using the language expressions represented by triangular fuzzy numbers enables avoiding the problem of decision makers` vagueness in expressing subjective preferences.

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