A fuzzy multi-criteria decision-making method for selection of criteria for an e-learning platform

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Abstract

Thanks to developing technology, one of the most significant changes in people's daily life routines have emerged in the education system. Due to developed software and hardware, people have begun to access, process, and share information regardless of time and place. Therefore, the internet-based teaching process, used alone or integrated with traditional education techniques, has brought many advantages and has become indispensable. Especially towards the end of 2019, the COVID-19 epidemic, which emerged in Wuhan, China, and spread worldwide, has again revealed that these systems have great importance for the future world. During the epidemic, traditional face-to-face education has been disrupted in many parts of the world, increasing online education. This situation has allowed increasing the number of studies on these systems. In particular, studies on the practical design of these systems are essential for the stakeholders of education systems. In this study, some significant criteria and sub-criteria are chosen based on literature and evaluated by using the fuzzy analytic hierarchy process.

Keywords: FAHP, Optimization, E-Learning, MCDM.

Bir e-öğrenme platformu kriter seçimi için bulanık çok kriterli karar verme yöntemi

Öz

Gelişen teknoloji sayesinde insanların günlük hayat rutinlerinde meydana gelen en büyük değişimlerden biri de eğitim sürecinde ortaya çıkmıştır. Geliştirilen yazılımlar ve donanımlar nedeniyle insanlar zaman ve mekandan bağımsız olarak bilgiye ulaşmaya, bilgiyi işlemeye ve paylaşmaya başlamışlardır. Tek başına veya geleneksel eğitim tekniklerine entegre olarak kullanılan internet tabanlı öğretim süreci pek çok avantajı da beraberinde getirmiş ve vazgeçilmez bir duruma gelmiştir. Özellikle 2019 yılının sonlarına doğru Çin'in Wuhan kentinde ortaya çıkan ve tüm dünyaya yayılan COVID-19 salgını bu sistemlerin geleceğin dünyası için büyük önem taşıdığını bir kere daha ortaya koymuştur. Salgın süresince geleneksel yüz yüze eğitim dünyanın pek çok bölgesinde sekteye uğramıştır ve online eğitim kullanımı artış göstermiştir. Bu durum bu sistemlerin konu edildiği çalışmaların da artmasına fırsat vermiştir. Özellikle bu sistemlerin etkili tasarımlarını konu alan çalışmalar eğitim sistemlerinin paydaşları için önem arzetmektedir. Bu çalışmada önemli kriter ve alt kriterler literatüre göre seçilmiş ve bulanık analitik hiyerarşi methodu kullanılarak değerlendirlimiştir.

Anahtar Kelimeler: FAHP, Optimizasyon, E-öğrenme, ÇKKV.

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1. Introduction

E-Learning is a modern methodology that aims to improve education by improving teaching and learning processes in digital environments. The most important feature of these systems is that they allow education regardless of time and place. The developing technology supports the improvement of new tools and methodologies used on these platforms. In this way, they have become an essential part of the education systems of developed and developing countries worldwide. The education sector includes many different stakeholders. Each stakeholder evaluates the sector from their perspective. E-learning has been an essential factor in increasing the performance of the education system and the satisfaction level of the education system participants by providing fast and easy access to information via the World Wide Web (www). One of the crucial aspects of this method is to present an effective interactive environment to participants. Successful implementation of an e-learning system depends on various criteria. Therefore, it is vital to determine and evaluate these criteria to develop a functional design of these systems (Naveed et al., 2020).

In literature, different approaches are deployed to evaluate critical success factors of e-learning systems. Lin et al. (2021) present a combined Fuzzy Analytic Hierarchy Process (FAHP) and Rule-Space Model methodologies to lead and evaluate students' learning status for online educational sites (C. T. Lin, Chang, & Chen, 2021). Upadhyay et al. (2021) present an analysis of the ergonomics-related disorders that can be emerged during online education by deploying FAHP to appraise ergonomics-related disorders. The disorders are identified, and these disorders' weights are figured out using triangle-shaped fuzzy numbers in pairwise comparison. The disorders are classified into four categories. These categories are evaluated and compared using FAHP according to their priorities (Upadhyay, Juneja, Juneja, Dhiman, & Kautish, 2021). Chandna et al. (2021) present a study comparing two open online courses: Coursera and edX. Noticeable aspects of these online education sites are determined and compared by using the FAHP method (Chandna, Saini, & Kumar, 2021). Li and Li (2020) present an organized math model for assessing online training system alternatives by using FAHP (L. Li & Li, 2020). Wang and Lin (2019) appraise e-learning systems according to importance by using an integrated model consisting of FAHP and Association Rule Mining methods. These methods are used to rank criteria for assessing e-learning systems (Wang & Lin, 2019). Turker Altun et al. (2019) presented a study to help institutions select an appropriate Learning Management Systems (LMS). FAHP, Fuzzy TOPSIS, and integrated method were used for evaluating criteria and deciding alternatives (Turker Altun, Baynal, & Turker, 2019). Yadegaridehkordi et al. (2018) present a new approach that incorporates FAHP and Structural Equation Modelling to appraise the relative weight and importance of the factors of cloud-based collaborative learning technology (Yadegaridehkordi, Nizam Bin Md Nasir, Fazmidar Binti Mohd Noor, Shuib, & Badie, 2018). Naveed et al. (2018) study the influence of barriers affecting e-learning systems. These barriers are appraised and prioritized by using FAHP to deal with them (Naveed et al., 2018). Anggrainingsih et al. (2018) study the e-learning success factors. FAHP method is used to determine the rank of factors' priorities (Anggrainingsih, Umam, & Setiadi, 2018). Pour et al. (2017) presents a framework for appraising e-learning systems by deploying FAHP and balanced scorecard methods (Jami Pour, Hosseinzadeh, Bagherzadeh Azar, & Taheri,

2017). Garg and Jain (2017) study the selection of E-learning websites by using the Fuzzy Multiple Attribute Decision-Making method. The selection index is constructed, and FAHP determines its weights. Then Complex Proportional Assessment (COPRAS), Multicriteria Optimization and Compromise Solution (VIseKriterijumska Optimizacija I Kompromisno Resenje-VIKOR), and Weighted Distance-based Approximation (WDBA) are used for ranking alternatives (Garg & Jain, 2017). Başaran and Haruna (2017) propose a model for quality and user satisfaction and evaluate mobile learning applications, particularly for mathematics, by applying FAHP and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) methods together (Başaran & Haruna, 2017). Kurilovas and Vinogradova (2016) present a methodology to assess the quality of distance learning courses. The methodology contains a criteria system and a new quality evaluation method established on Fuzzy and AHP methods (Kurilovas & Vinogradova, 2016). Nagpal et al. (2015) present a study to evaluate the usability of the website of an educational institute by using FAHP (Nagpal, Mehrotra, Bhatia, & Bhatia, 2015). Mazaheri et al. (2015) present an assessment framework to evaluate the students' performance in e-learning systems. Six main criteria and 24 sub-criteria are determined and evaluated by using FAHP (Mazaheri Asad, Ebrahimi Kermani, & Monteiro da Hora, 2015). Işık et al. (2015) use FAHP methodology to evaluate and select a suitable LMS (Işık, Ince, & Yigit, 2015). Chang et al. (2015) use the Fuzzy Delphi method (FDM) and Fuzzy FAHP to determine the critical success factors of knowledge management for university students using e-portfolio (Chang, Liang, Shu, & Tsai, 2015). Wang and Lin (2012) use FAHP and Association Rule to assess the process of "Practice Score" and "Interactive Learning" (Wang & Lin, 2012). Wan et al. (2012) use FAHP to evaluate the Learning Content Management System (LCMS) and select the best LCMS according to qualitative and quantitative criteria (Wan, Shi, & Zhao, 2012). Li et al. (2012) present an assessment index system for evaluating internet learning quality (W. Li, Gao, & Fu, 2012). Mehregan et al. (2011a) present a study to identify and prioritize e-learning critical success factors (CSFs) to help educational institutes and universities for developing e-learning system plans (Mehregan, Jamporazmey, Hosseinzadeh, & Mehrafrouz, 2011a). Mehregan et al. (2011b) present an approach to identify and prioritize the critical success factors (CSFs) of e-learning systems by using FAHP (Mehregan, Jamporazmey, Hosseinzadeh, & Mehrafrouz, 2011b). Lo et al. (2011) construct a hierarchical factor table by using FAHP for firms implementing customized e-learning systems (Lo, Chang, Shieh, & Chung, 2011). Yang and Chen (2010) analyze students' self-learning ability in a network environment using fuzzy mathematics. Then, AHP is used to build students' self-learning evaluation index system and evaluation model (Yang & Chen, 2010). Xing (2010) used FAHP to establish a model for evaluating web-based courses (Xing, 2010). Tseng et al. (2010) present an approach to establish an adaptive curriculum portfolio recommendation system (Tseng, Chang, & Chou, 2010). Lin (2010) presents an approach in which FAHP and fuzzy triangular numbers are integrated to identify the factors influencing the effectiveness of a course website (H. F. Lin, 2010). Jie (2010) presents a literature review to determine criteria and sub-criteria for online course quality assessment. A fuzzy evaluation model is deployed to prioritize the relative weights of online course quality factors (Jie, 2010). Hong (2010) present an assessment framework to determine the sustainability of virtual communities under e-learning platform in university, and FAHP is used for data pairwise comparison (Hong, 2010). Liu et al.

(2009) use FAHP to assess the factors influencing an e-learning platform (Liu, Peng, Chen, & Xie, 2009). Chen (2019) assesses e-learning service companies by identifying and prioritizing their measures of intellectual capital (Chen, 2009). Chao and Chen (2009) assess a web e-learning system by using the consistent fuzzy preference relations (CFPR) in the AHP model by examining several criteria (Chao & Chen, 2009). Bo et al. (2009) assess the capability of network education in China. The fuzzy synthetic judgment method and AHP are used to build an assessment system (Bo, Xuning, & Bingquan, 2009).

This study uses the FAHP method to assess the criteria and sub-criteria to decide the most important ones for e-learning. Previous studies are examined and used criteria, and sub-criteria are determined by investigating extensive literature review studies (Naveed et al., 2020; Zare et al., 2016). Finally, seven criteria and thirty-one sub-criteria are chosen and evaluated by experts.

2. Material and Method

2.1. Evaluation Criteria

In this study, seven main criteria and thirty-one sub-criteria are selected based on the literature to evaluate the e-learning platform of Cumhuriyet University. All of the criteria are presented in Table 1.

Table 1. Main and sub-criteria.

Main Criteria	Sub Criteria
Framework (C1)	C11 Navigation
	C12 Offline access
	C13 User-friendliness
	C14 Report
Function (C2)	C21 User control
	C22 History
	C23 Search
	C24 Lecture duration control
	C25 Customization
	C26 Whiteboard sharing
Security (C3)	C31 Authorization
	C32 Password security
	C33 Virus protection
	C34 Authentication
Material (C4)	C41 Sufficient education material
	C42 Pedagogical material
	C43 Additional material
	C44 Document library
Collaboration (C5)	C51 Data sharing
	C52 Mail-message
	C53 Content sharing
	C54 Questioner
	C55 Interactive mode
Quality (C6)	C61 System user satisfaction
	C62 Internet connection quality
	C63 Audit
	C64 Up-to-date content
Assessment (C7)	C71 Exercises-Quizzes Exams
	C72 Attendance
	C73 Progress tracking
	C74 Projects

The criteria, namely, Framework (C1), contains four sub-criteria. The sub-criteria of Framework (C1) are Navigation (C11), Offline Access (C12), User-Friendliness (C13), and Report (C14).

- Navigation is related to the clearness and easiness of navigation in the platform's menus, interfaces, or subpage hierarchy.
- Offline access is related to accessing videos or documents of lessons offline.
- User-friendliness meaning is that the portal is easy to understand and use; has desirable interfaces which increase user satisfaction.
- The report is the ability of portal framework design to give customized or standard reports to users.

The criteria, namely, Function (C2), contains six sub-criteria. These are user control (21), history (22), search (23), lesson duration control (24), customization (25), and whiteboard sharing (26).

- User control is related to the ability of both academicians and students to organize learning activities.
- History gives the records of the learning process such as lesson durations, video uploading times, internet connection history, user activity information, etc.
- Search is the effectiveness of this function to access intended information in the platform.
- Lesson duration control is the easiness of controlling the duration of an online lesson and video records by academicians.
- Customization is related to the customization degree of a platform according to user desires/needs.
- Whiteboard sharing is a platform's capability to enable academicians to share whiteboards during online lessons.

The criteria, namely, Security (C3), has four sub-criteria. These are authorization (C31), password reset (C32), virus protection (C33), authentication (C34).

- Authorization is related to the degree of permissions given to users during the platform's usage.
- Password security is the easiness and security of getting new robust passwords by users and restoring the account.
- Virus protection is the effectiveness of anti-virus protection of the platform.
- Authentication is related to verifying the identity of users and processes.

The criteria, namely, Material (C4), has four sub-criteria. These are sufficient education material (C41), pedagogical material (C42), additional material (C43), and document library (C44).

- Sufficient Education material is related to the richness of materials used in lessons.
- Pedagogical material related to pedagogic consideration in used/shared materials.
- Additional material is related to the richness of additional materials are offered by academicians in the training process.
- Document library enables users to manage, update, distribute and use educational documents.

The criteria, namely, Collaboration (C5), has five sub-criteria. These are data sharing (51), mail/message (52), content sharing (53), questionnaire (54), and interactive mode (55).

- Data sharing lets users share related data during online lessons or offline.
- Mail/message lets users communicate during online lessons or offline.
- Content sharing is related to communicating using other platforms such as social media, Document Library, Google Drive, WeTransfer, One Drive.
- The questionnaire enables the academicians to share various questionnaires with students.
- Interactive mode is presented that the portal has interactive learning processes.

The criteria, namely, Quality (C6), has four sub-criteria. These are system user satisfaction (61), connection quality (62), content audit (63), and up-to-date content (64).

- User satisfaction gives overall satisfaction pf users from the platform.
- Connection quality shows the internet connection capability in terms of speed, stability, quota, disconnection, etc.
- The audit is a control mechanism that is a process of systematically reviewing all the content in the platform and evaluating students
- Up-to-date content provides all of the content to be up to date, which increases user satisfaction.

The last criteria, namely, Assessment (C7), has four sub-criteria. These are exercises/quizzes/exams (71), attendance (72), progress tracking (73), and projects (74).

- Academicians do exercises/quizzes/exams to assess the success of students.
- Attendance is checked to meet course pass requirements.
- Progress tracking enables academicians to track students' overall success in projects, exams, and other activities.
- Projects are additional assessment criteria in training.

2.2. Fuzzy AHP

In decision-making problems, linguistic expressions are subjective, and vagueness and uncertainty of decision settings can reason problems during the evaluation of decision-makers. The fuzzy sets can be used to handle such problems in modeling so that more exact results can be achieved. Fuzzy sets were proposed by Zadeh (1965). A membership function characterizes each element in a fuzzy set by assigning the elements to set with membership degrees in the range of [0,1]. There are various types of fuzzy sets in the literature such as type-1, type-2 fuzzy sets, intuitionistic fuzzy sets, hesitant fuzzy sets, etc. (Güldeş, Atici, & Şahin, 2021; Gürcan, Yazıcı, Beyca, Arslan, & Eldemir, 2016; Yazici et al., 2020).

The Multi-Criteria Decision Making (MCDM) techniques are widely applied in decision-making problems (Akcan & Güldeş, 2019). These techniques give mathematical methodology that involves values of stakeholders and decision-makers besides technical information to choose the best solution for different problems. MCDM enables more logical and scientifically defendable decisions to be made. A typical MCDM application has the following processes: The problem is defined where overall structure and decision-makers are described. The problem is structured by defining related alternatives and criteria. The criteria are used in deciding on alternatives. Then, criteria and alternatives are assigned numeric values. Criteria are weighted by decision-makers. The alternatives get scored overlooking criteria. Model is applied using criteria weights and scoring of alternatives (Linkov & Moberg, 2011).

There are many MCDM techniques. The best alternative is determined with quantitative and qualitative criteria and frequently with conflicting criteria. One of the widely used techniques is Analytical Hierarchy Process (AHP), which was developed by Saaty (Saaty, 1977, 1980). AHP is an incredibly beneficial method when the decision-maker is inadequate to build a utility function. There are four steps in obtaining a rank for alternatives in the AHP application. Firstly, the problem should be structured like a typical property of MCDM methods. The problem is structured using a hierarchy including some levels such that level of goal of problem, criteria, sub-criteria, and alternatives. Then priorities (priorities of criteria, local alternative, and global alternative) or scores are calculated depending on pairwise comparisons ensured by the user. A numerical judgment is not obligatory for decision-makers. A relative verbal evaluation is sufficient. Later, a consistency check and a sensitivity analysis are made, optional but advised to obtain robust results. A consistency check helps to reveal possible contradictions in input data. On the other hand, sensitivity analysis lets different scenarios be produced, where input data is changed slightly to monitor the impact on results. As a result, different scenarios can give the same alternatives (robust results), or ranking can be changed (sensitive results) (Ishizaka & Nemery, 2013).

In this study, we decided to use Type-1 fuzzy sets with the AHP technique. The linguistic variables and related fuzzy scales used in the current study are given in Table 2.

Table 2. Linguistic variables and fuzzy triangular numbers.

Linguistic Variables	Fuzzy scale
Equally Important	(1, 1, 1)
Moderately Important	(2, 3, 4)
Strongly Important	(4, 5, 6)
Very Strongly Important	(6, 7, 8)
Absolutely Important	(9, 9, 9)

Pairwise comparisons matrices are produced, given in Equation (1), considering pairwise comparisons between the criteria. The corresponding linguistic expressions are determined to compare the importance of the criteria. The fuzzy geometric mean is found applying Equation (2).

$$\widetilde{M} = \begin{bmatrix} 1 & \widetilde{m}_{12} & \widetilde{m}_{13} & \dots & \widetilde{m}_{1n} \\ \widetilde{m}_{21} & \widetilde{m}_{22} & \widetilde{m}_{23} & \dots & \widetilde{m}_{2n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ \widetilde{m}_{n1} & \widetilde{m}_{n2} & \widetilde{m}_{n3} & \dots & 1 \end{bmatrix} \quad (1)$$

$$\tilde{g}_i = (\widetilde{m}_{i1} \otimes \widetilde{m}_{i2} \otimes \dots \otimes \widetilde{m}_{in})^{1/n} \quad (2)$$

The fuzzy weight of each criterion is found using Equation (3). The vector sum of each $\tilde{g}_i$ is attained.

$$\widetilde{w}_i = \tilde{g}_{i\otimes}(\tilde{g}_1 \otimes \tilde{g}_2 \otimes \dots \otimes \tilde{g}_n)^{-1} \quad (3)$$

The performance value of each criterion is calculated using Equation (4), where P is a non-fuzzy value. In this equation, (u, m, l) is a triangular fuzzy number where u, m, l present the the highest, mid, the lowest possible value of an fuzzy event, respectively. Then, it is normalized using Equation (5).

$$P_i = \frac{lw_i + mw_i + uw_i}{3} \tag{4}$$

$$w_i = \frac{P_i}{\sum_{j=1}^{n} P_i} \tag{5}$$

A fuzzy set, $\tilde{F}$ is defined in [0, 1] presented in Equation (6).

$$\mu_{\tilde{F}} : E \rightarrow [0,1] \tag{6}$$

$$\mu_{F(x)} \begin{cases} 0, & x \leq a \\ \frac{x-a}{b-a} & a \leq x \leq b \\ \frac{c-x}{c-b} & b \leq x \leq c \\ 0, & x \geq c \end{cases}$$
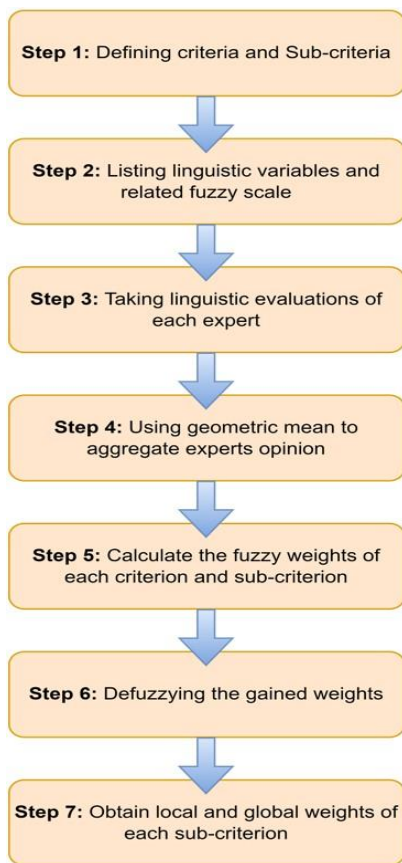
The steps of the FAHP process are summarized in Figure 1.

Figure 1. Steps of FAHP process.

2.3. e-Learning System of Cumhuriyet University

Due to the Covid 19 epidemic, distance education was provided at Sivas Cumhuriyet University in the spring term of 2020-2021. Hybrid education is offered in the recent spring semester: face-to-face and online.

In the spring semester, Atatürk's Principles and Revolution History, Turkish Language and Foreign Language courses within the scope of the 5i, which are compulsory in all programs, and İLİTAM program courses are conducted online.

Distance education consists of three platforms: Student Information System (SIS), Learning Management System (LMS), and Microsoft Teams. These platforms can work over the web, and users log in under authentication and authorization procedures. Institutional e-mail addresses, passwords, student or academic staff registration numbers, and ID numbers are needed. The integrated e-learning system of Cumhuriyet University is presented in Figure 2.
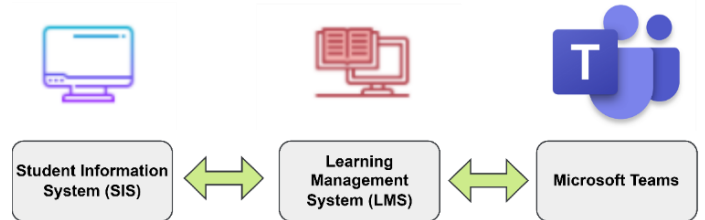

Figure 2. The integrated e-learning system of the university.

Microsoft Teams: Online lessons are held over the Microsoft Teams system. Therefore, this program must be installed on a user's computer or mobile phone. Online lessons are held during the lesson hours specified in the lesson program and defined in the Microsoft Teams system. A make-up program is made for the lessons that cannot be completed on time or delayed. Students sign up for live classes (aka classes or teams) using Microsoft Teams. The team code required to become a member announces on the LMS or SIS. Online lessons cannot be watched without the team code. With Microsoft Teams working on the web, installing Teams on computers, tablets, and mobile phones allows the online lesson to run more smoothly. Watching the videos in the archive is also done through Microsoft Teams.

Learning Management System (LMS): The courses to be taken by the students are uploaded to the LMS. The links of the courses with video footage are added in LMS in the relevant weeks. In addition, to live lessons, pdf, ppt, lecture notes, etc., course materials are uploaded to LMS. The authorities do the tracking of whether the course materials are uploaded in the relevant week via LMS. Giving homework, projects, and applications to students and uploading them to the system by students is done via LMS. LMS is used to take online exams. Academic advisors are responsible for solving possible problems that students with disabilities may encounter in distance education. Messages sent by students via LMS are frequently checked and answered by academicians as soon as possible. Additionally, students can access exam information and various announcements via this platform. The LMS interface is given in Figure 3.
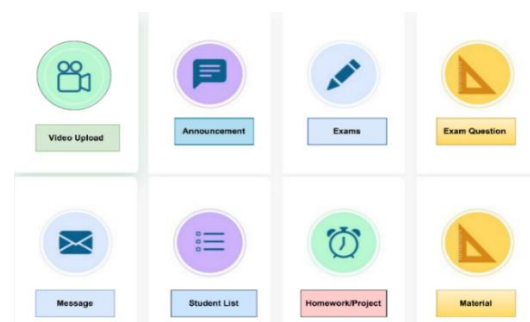

Figure 3. LMS interface.

Student Information System (SIS) is an academic information system. This system gives information on course processes (such as academic calendar, syllabus), student advising process (such as course registration, listing students being advisor, graduation permission), exam process (such as exam calendar, exam results, exam registration), some user processes (such as academic CV, HES code, announcements, messages, user profile information).

3. Result and Discussion

Seven main criteria and thirty-one sub-criteria have been determined for the evaluation of our university's e-learning system. Which features should be given more importance in the development of the current learning system was determined by using the FAHP method. Evaluations were made by a team of experts (ET) working in administrative and academic positions. A summary linguistic evaluations of criteria is presented in Table 3.

Geometric means were calculated using Equation (2). After calculating the geometric mean of the main criteria, the fuzzy weights of the sub-criteria are calculated. The geometric mean of fuzzy comparison value for each sub-criterion is presented in Table 4.

The relative fuzzy weight of each criterion is calculated by using Equation (3). The relative fuzzy weight of each criterion is shown in Table 5.

The calculated weights are defuzzified and normalized. The criteria weights normalized by averaging are presented in Table 6. The calculated ranked weights of main and sub-criteria are presented in Table 7 and Table 8, respectively.

Table 3. The linguistic evaluations of criteria.

	C1	C2	C3	⋯	C31
C1	EE	C1&C2	C1&C3	⋯	C1&C31
C2	1/C1&C2	EE	C2&C3	⋯	C2&C31
C3	1/C1&C3	1/C2&C3	EE	⋯	C3&C31
⋮	⋮	⋮	⋮	⋮	⋮
C31	1/C1&C31	1/C2&C31	1/C3&C31	⋯	EE

Table 4. The geometric mean of fuzzy comparison.

Criteria	r_i		
C11 Navigation	0.277	0.303	0.255
C12 Offline access	4.315	4.415	3.745
C13 User friendly	0.450	0.443	0.434
C14 Report	0.319	0.396	0.401
C21 User control	0.365	0.357	0.417
C22 History	0.356	0.321	0.346
C23 Search	0.411	0.405	0.438
C24 Lecture duration control	0.371	0.405	0.451
C25 Customization	0.418	0.376	0.429
C26 Whiteboard sharing	1.720	1.606	1.620
C31 Authorization	1.445	1.560	1.491
C32 Password security	2.564	3.076	2.643
C33 Virus protection	2.568	2.854	2.607
C34 Authentication	2.055	1.694	1.966
C41 Sufficient education material	2.600	2.819	2.751
C42 Pedological material	2.207	2.378	2.244
C43 Additional material	1.168	1.166	1.172
C44 Document library	0.735	0.730	0.743
C51 Data sharing	0.651	0.580	0.621
C52 Mail-message	0.609	0.591	0.611
C53 Content sharing	0.891	0.857	0.907
C54 Questionary	0.979	0.992	0.966
C55 Interactive mode	1.300	1.407	1.323
C61 System user satisfaction	0.640	0.659	0.655
C62 Internet connection quality	2.852	2.902	2.917
C63 Content audit	1.994	1.983	1.970
C64 Up-to-date content	1.851	2.008	2.053
C71 Exercises-Quizes Exams	3.493	3.397	3.734
C72 Attendance	0.895	0.887	0.910
C73 Progress tracking	1.054	1.075	1.094
C74 Projects	0.290	0.297	0.326

Table 5. Relative fuzzy weight of criteria.

Criteria	w_i		
C11 Navigation	0.006	0.007	0.006
C12 Offline access	0.100	0.105	0.090
C13 User friendly	0.010	0.010	0.010
C14 Report	0.007	0.009	0.010
C21 User control	0.008	0.008	0.010
C22 History	0.008	0.008	0.008
C23 Search	0.010	0.010	0.010
C24 Lecture duration control	0.009	0.010	0.011
C25 Customization	0.010	0.009	0.010
C26 Whiteboard sharing	0.040	0.038	0.039
C31Authorization	0.034	0.037	0.036
C32 Password security	0.060	0.073	0.063
C33 Virus protection	0.060	0.068	0.062
C34 Authentication	0.048	0.040	0.047
C41 Sufficient education material	0.061	0.067	0.066
C42 Pedological material	0.051	0.056	0.054
C43 Additional material	0.027	0.028	0.028
C44 Document library	0.017	0.017	0.018
C51 Data sharing	0.015	0.014	0.015
C52 Mail-message	0.014	0.014	0.015
C53 Content sharing	0.021	0.020	0.022
C54 Questionary	0.023	0.023	0.023
C55 Interactive mode	0.030	0.033	0.032
C61 System user satisfaction	0.015	0.016	0.016
C62 Internet connection quality	0.066	0.069	0.070
C63 Content audit	0.046	0.047	0.047
C64 Up-to-date content	0.043	0.048	0.049
C71 Exercises-quizes-exams	0.081	0.080	0.089
C72 Attendance	0.021	0.021	0.022
C73 Progress tracking	0.025	0.025	0.026
C74 Projects	0.007	0.007	0.008

Tablo 6. Average and normalized weight of criteria.

Sub- criteria	μ_i	n_i
C11 Navigation	0.007	0.00657
C12 Offline access	0.098	0.09815
C13 User friendly	0.010	0.01045
C14 Report	0.009	0.00879
C21 User control	0.009	0.00897
C22 History	0.008	0.00805
C23 Search	0.010	0.00987
C24 Lecture duration control	0.010	0.00966
C25 Customization	0.010	0.00963
C26 Whiteboard sharing	0.039	0.03892
C31 Authorization	0.035	0.03540
C32 Password security	0.065	0.06523
C33 Virus protection	0.063	0.06322
C34 Authentication	0.045	0.04498
C41 Sufficient education material	0.064	0.06433

C42 Pedological material	0.054	0.05377
C43 Additional material	0.028	0.02760
C44 Document library	0.017	0.01738
C51 Data sharing	0.015	0.01458
C52 Mail-message	0.014	0.01426
C53 Content sharing	0.021	0.02090
C54 Questionary	0.023	0.02311
C55 Interactive mode	0.032	0.03173
C61 System user satisfaction	0.015	0.01539
C62 Internet connection quality	0.068	0.06827
C63 Content audit	0.047	0.04682
C64 Up-to-date content	0.047	0.04657
C71 Exercises-Quizes Exams	0.084	0.08366
C72 Attendance	0.021	0.02120
C73 Progress tracking	0.025	0.02537
C74 Projects	0.007	0.00718

Table 7. Ranked global weights main criteria.

Main criteria	n_i
Security (C3)	0.208864671
Quality (C6)	0.177068088
Material (C4)	0.163103562
Assessment (C7)	0.13743323
Framework (C1)	0.123984207
Collaboration (C5)	0.104599908
Function (C2)	0.085117475

Table 8. Ranked weights sub-criteria.

Sub- criteria	n_i
C12 Offline access	0.098153
C71 Exercises-Quizes Exams	0.083656
C62 Internet connection quality	0.068271
C32 Password security	0.065228
C41 Sufficient education material	0.06433
C33 Virus protection	0.063221
C42 Pedological material	0.053767
C63 Audit	0.046815
C64 Up-to-date content	0.046565
C34 Authentication	0.044975
C26 Whiteboard sharing	0.038922
C31 Authorization	0.035404
C55 Interactive mode	0.03173
C43 Additional material	0.027601
C73 Progress tracking	0.025372

4. Conclusions and Recommendations

Due to the COVID-19 pandemic, the use of distance education systems has become widespread. Many different institutions, from health to universities, continued their education activities through distance education systems. Therefore, it should be determined which criteria will be used to develop LMS systems and which features of LMS systems are essential for academics, students, and users.

In this study, the criteria to develop the LMS system selected for the application study were determined. FAHP multi-criteria decision-making method was used.

In this study, the criteria and sub-criteria were selected by a comprehensive literature review. The fuzzy analytical hierarchy method was used to prioritize the e-learning platforms criteria. Seven criteria and 31 sub-criteria were determined to evaluate e-learning platforms. According to the weight values, the first three main criteria were Security (C3), Quality (C6), and Material (C4). Security (C3), which means the security of information such as account, evaluation system, and exam results, has been the most critical criterion. It has been determined that account reliability concerns over the entire system take precedence over other criteria. Here, ET has prioritized its concerns regarding the storage of exam questions and results. ET gives second

importance to Quality (C6). The second priority was given to the reliability of the internet connection and the supervision of the evaluation mechanism of the students, which are necessary conditions for distance education. ET is the third most crucial criterion, Material (C4).

According to the global weight values first ten sub-criteria are with C12 Offline access, C71 Exercises-Quizzes Exams, C62 Internet connection quality, C32 Password security, C41 Sufficient education material, C33 Virus protection, C42 Pedological material, C63 Audit, C64 Up-to-date content.

This study presents a reasonable criterion for determining the features to be prioritized in the development of LMS systems. Furthermore, the method proposed in this study can be used to determine which features will be improved in updating other e-learning systems.

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