THE EVALUATION OF LEARNING MANAGEMENT SYSTEMS BY USING FUZZY AHP, FUZZY TOPSIS AND AN INTEGRATED METHOD: A CASE STUDY

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ABSTRACT

Distance Education has become an important educational model with the development of information and communication technologies in the world. It has also become increasingly used model in Turkey. In our country, the number of universities and educational organizations offering distance education programs increase day by day. Distance education is performed by some special software called Learning Management System (LMS). There are both commercial LMSs and several open-source LMSs that have cost advantages. It is difficult to select an appropriate LMS for many institutions to meet their standards. The decision making and selection process is crucial, because LMS functions are different from each other, and they all have various features. Because of this, in this study, it is targeted to help and facilitate the decision-making process of LMS for institutions. In this study, Fuzzy AHP (Analytic Hierarchy Process), Fuzzy TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) and an integrated method were used for evaluating criteria and deciding alternatives. To help accomplish this aim, questionnaire forms was designed and used for data collection. These methods were compared with each other. Results were evaluated. According to results among different criteria, the most important criteria for selecting LMS alternatives was found Content Management and Development (96.3%) and between the alternatives Moodle was found the best alternative with the degree of 36.3%.

Keywords: Fuzzy AHP, fuzzy TOPSIS, learning management system, distance education.

INTRODUCTION

In today's information age, computer and information technologies improve rapidly day by day. Thanks to developing technologies, the human life has become easier. The changing education model can be showed as an example of easier life. Rapid technological developments and the widespread usage of the Internet, has

caused changes in the understanding of education and distance education has become an important role in teaching and learning.

Distance education is a way of teaching and planned learning in which teaching activities occurs in a different place from special courses, teaching techniques and communication by using technology (Moore and Kearsley, 2005). It varies according to the face-to-face training in terms of courses management, teacher roles, instructional design, interaction strategies, the support systems given to learners, evaluation process and general administrative services (Olcott, 2003; Stella and Gnanam, 2004) and it can be performed some tools such as computer and multimedia technology. Thus, the concept of distance education or e-learning has emerged. Because e-learning activities are performed in web, the concept of distance education and e-learning started to be used interchangeably. E-learning is a subset of distance education that was common since the middle of 1980s (Hassanzadeh et al., 2012). E-learning can be defined as; the distribution of required information for education and training with communication tools (Sun et al., 2008; Reis et al., 2012) or using internet and new multimedia technologies for improve quality of education by facilitating access to education resources with services like co-operation and sharing information (Itmazi et al., 2005; Reis et al., 2012). With spread internet usage, e-learning became vastly widespread and many universities put it in their program (Kanuka and Anderson, 2007). According to the Giga Information Group, nearly 75% of the 129 top US universities use e-learning systems (Wang and Wang, 2009) and 95% of higher education institutions in the UK have established e-learning systems (Browne et al., 2006; Loon and Teasley, 2009). The number of universities offering distance education in Turkey is increasing as time goes on. The number of the universities offering distance education refers to nearly 80% of the total number of universities.

The distance education is performed by some special software called Learning Management Systems. LMS is an e-learning infrastructure and has many functions such as creating time-independent course materials, monitoring, sharing and discussing of these materials at anytime and anywhere, updating and reporting all of the systems information. There is commercial and open source software used in e-learning. Many universities prefer the open-source software for e-learning. By this way, the cost disadvantages of e-learning are largely eliminated (Aydin and Birogul, 2008). ATutor, Ada, Moodle, Claroline, Ilias, Docebo, Dokeos, COSE, Olat, Sakai, TinyLMS, Jones e-education, Kewl-Nextgen and Fle3 are example of open-source software. As it is seen, there are different LMS types so we can say that it is difficult to select an appropriate LMS for many universities to meet their standards. The decision making and selection process is crucial because LMS functions are different from each other, and they all have various features. Because of this, in this study, it is targeted to help and facilitate the decision-making process of LMS for universities. We can say that, the aim of this study is to evaluate the criteria of LMS selection and decide the LMS alternatives according to defined criteria. We think that, this study is helpful for both universities and educational organizations to decide which type of LMS is preferred.

In the study Fuzzy AHP (FAHP), Fuzzy TOPSIS and an integrated method is used for evaluating process. In the literature, AHP and TOPSIS methods were applied to different areas and a limited number of studies on selecting LMS evaluation with AHP existence and there has not been yet a study using TOPSIS method or AHP-TOPSIS integrated on LMS evaluation. With this study, we want to fill this gap in the literature.

The remainder of this paper is organized as follows. Section 2 presents literature review on LMS and integrated fuzzy AHP-TOPSIS papers. Section 3 talks about Fuzzy Multiple Criteria Decision Making (MCDM). Section 4 represents the case study. The paper is concluded and the future directions are highlighted in Section 5.

LITERATURE REVIEW

Literature Review on Learning Management System

In the literature, there are different studies regarding to defining Learning Management System criteria, comparing and evaluating LMS alternatives. Some of these are as following. Kaya (2012) investigated the LMS usage at universities in Turkey and Northern Cyprus. Which university uses which LMS is shown and the most used LMS was defined as MOODLE in this study. Reis et al. (2012) mentioned open-source LMS for web based learning, defined different evaluation criteria and made a detailed comparison of some of the open-source LMS alternatives based on these criteria. Alshomrani (2012) compared 8 LMS alternatives in terms of approximately 25 technical specifications. Usability, Collaboration features, Support for learning methods, Standards-oriented content authoring / importing such as IMS and SCORM, Multi Lingual Support were seen as the key points of technical specification and it showed the alternatives that meets these specifications were Moodle, ATutor and ILLIAS respectively. Cavus (2010) evaluated open-source LMS and commercial LMS by using an artificial intelligence fuzzy logic algorithm. At the end of study WebCT 4.0 for commercial LMS and MOODLE for open-source LMS were seen as the best LMS.

Chao and Chen (2009) presented a method to evaluate the LMS factors. By using consistent fuzzy preference relations (CFPR) in AHP, e-learning material was defined as the main criteria and the other criteria was defined as Quality of web learning platform, Synchronous learning, Self-learning, Learning record respectively. Chen and Li (2009) used fuzzy analytic hierarchy process to evaluate alternatives of distance education system in China. At the end of the study, Furite (an LMS alternative) was observed as the best alternative. Shee and Wang (2008) carried out a survey of college students to evaluate web based e-learning and AHP was used for analyzing the result of survey and Learner interface has been observed as the most important criteria. Aydin and Birogul (2008) gave information about open-source LMS, compared existing LMS and observed MOODLE is the best alternative. Colace and De Santo (2008) evaluated e-learning platform with AHP under 3 different scenarios.

Literature Review on Integrated AHP-TOPSIS Studies

In the literature, Integrated AHP-TOPSIS Studies can be seen. AHP-TOPSIS were used together; Tsaur et al. (2002) to evaluate the quality of airport services, Majumdar et al. (2005) to determine the quality value of cotton fibre; Mahmoodzadeh et al. (2007) for project selection Shyjith et al. (2008) to evaluate optimum maintenance strategy in textile industry, Yu et al. (2011) to rank business to customer (B2C) e-commerce websites in e-alliance Bakhoum and Brown (2013) for sustainable ranking of structural materials and Goh et al. (2013) used shedding scheme for large pulp mill electrical system.

Fuzzy MCDM

Multi criteria decision making problems often involve uncertainty and these problems are inherently vagueness and fuzziness. Fuzzy set theory was introduced by Zadeh (1965) and he used these problems to provide a mathematical way to represent vagueness and fuzziness in humanistic systems. It implements classes and grouping of data with boundaries that are not sharply defined (i.e., fuzzy) and it is easier to understand (Chan and Kumar, 2007).

Fuzzy AHP

Analytic hierarchy process (AHP) is a multi-criteria decision making method introduced by Saaty in 1970s and uses a pair-wise comparison method to obtain relative weights of criteria and alternative scores. The AHP is one of the most widely used MCDM methods. In spite of AHP method popularity; this method is often criticized because of its inability to handle uncertain and imprecise decision-making problems (Cheng 1999, Chan et al. 2008, Lee 2009). To eliminate this uncertainty in the decision making problems Fuzzy AHP based on fuzzy set theory was originally introduced by van Laarhoven and Pedrycz (1983). Later,

academics have developed and used various fuzzy AHP methods for solving different problems (Chang 1996; Cheng et al., 1999; Mikhailov 2002; Kahraman et al., 2004; Gu and Zhu, 2006).

Chang (1996) introduced a new approach for handling pair-wise comparison based on triangular fuzzy numbers followed by use of extent analysis method for synthetic extent value of the pair-wise comparison. Traditional fuzzy AHP methods deal with fuzzy values by using tiring arithmetic calculations. Furthermore, another disadvantage of these methods is that they need more defuzzification process for achieving a certain result. Because of using the intersection of triangular fuzzy numbers method for calculations, these disadvantages are not valid for Chang's approach (Demirel et al., 2009). Therefore, Chang's approach has been used in this study. Linguistic variables and triangular fuzzy numbers (TFN) used in Fuzzy AHP are shown in Table 1.

Table 1. Linguistic variables and triangular fuzzy numbers for the evaluation

Linguistic term	TFN	Inverse TFN
Equally important	(1,1,1)	(1,1,1)
Weakly important	(1,3,5)	(1/5, 1/3, 1/1)
Essentially important	(3,5,7)	(1/7, 1/5, 1/3)
Very strongly important	(5,7,9)	(1/9, 1/7, 1/5)
Absolutely important	(7,9,9)	(1/9, 1/9, 1/7)

Fuzzy TOPSIS

The TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) which was developed by Hwang and Yoon (1981) is one of the most popular ideal point methods. The method uses the concepts of a positive ideal solution and a negative ideal solution to solve MCDM problems. The best alternative should have the shortest distance from the positive-ideal solution point and the longest distance from the negative-ideal solution point (Razmi et al. 2009). Chen (2000) extended this method to fuzzy group decision making, using triangular fuzzy numbers and describing Euclidean distance between two fuzzy numbers. Fuzzy TOPSIS is applied in this study because of its basic concept and wide applications, such as those described by Shih (2008) and Chen and Hung (2010). Linguistic terms and triangular fuzzy numbers, used in Fuzzy TOPSIS are shown in Tables 2 and Table 3.

Table 2. Linguistic terms and fuzzy membership functions for criteria weights

Linguistic term	Fuzzy membership functions
Very high (VH)	(0.9,1,1)
High (H)	(0.7,0.9,1)
Medium High (MH)	(0.5,0.7,0.9)
Medium (M)	(0.3,0.5,0.7)
Medium low (ML)	(0.1,0.3,0.5)
Low (L)	(0,0.1,0.3)
Very low (VL)	(0,0,0.1)

Table 3. Linguistic terms and fuzzy membership functions for alternatives

Linguistic term	Fuzzy membership functions
Very good (VG)	(9,10,10)
Good (G)	(7,9,10)
Medium good (MG)	(5,7,9)
Fair (F)	(3,5,7)
Medium poor (MP)	(1,3,5)
Poor (P)	(0,1,3)
Very poor (VP)	(0,0,1)

CASE STUDY

In the literature, AHP and TOPSIS methods were applied to different areas and a limited number of studies on selecting LMS evaluation with AHP existence and there has not been yet a study using TOPSIS method or AHP-TOPSIS integrated on LMS evaluation. In this study, these two methods are used both separately and integratedly. The steps are as following;

Step 1: Establishing a committee of experts who are working at distance education department of different universities and determining the alternatives and sets of criteria and sub-criteria for evaluation. Criteria shown in Table 4 are defined according to users and expert opinions and other studies in literature (Shee and Wang, 2008; Aydin and Birogul, 2008; Ozan, 2008; Chao and Chen, 2009; Aydin and Tirkes, 2010; Reis et al., 2012). Alternatives are shown in Table 5. Popularity degree and common usage characteristic are taken into account during defining alternatives. Questionnaire forms used in this study are presented in Table 1-4 in the Appendix. Experts identified their opinions through linguistic scale in Table 1-3.

Table 4. Main and Sub-Criteria for LMS evaluation

Main Criteria	Sub-Criteria
C_1: Ease of Use	C_{11}: Friendly Interface
	C_{12}: Flexible Systems
C_2: Communication, Interaction and Cooperation	C_{21}: Discussion / Forum
	C_{22}: Whiteboard
	C_{23}: Video Conferencing Support
	C_{24}: Social Networking
C_3: Content Management and Development	C_{31}: Compliance with Teaching Standards
	C_{32}: Content Sharing Tools
	C_{33}: Course Templates
C_4: Support	C_{41}: Online Help

	C_{42}: Educational Support
C_5: Productivity Tools	C_{51}: Calendar
	C_{52}: Searching Engine
	C_{53}: Help Tool
C_6: Measuring Tools	C_{61}: Test / Exam tools
	C_{62}: Question Bank Management
	C_{63}: Automated Test Management
C_7: Evaluation Tools	C_{71}: Student Tracking
	C_{72}: Courses / Training management
C_8: Security	C_{81}: Authentication
	C_{82}: The Frequency of Publication of Security Patch

Table 5. LMS Alternatives

Code	Alternative
A1	ATutor
A2	Claroline
A3	Sakai
A4	Moodle
A5	OLAT
A6	Dokeos

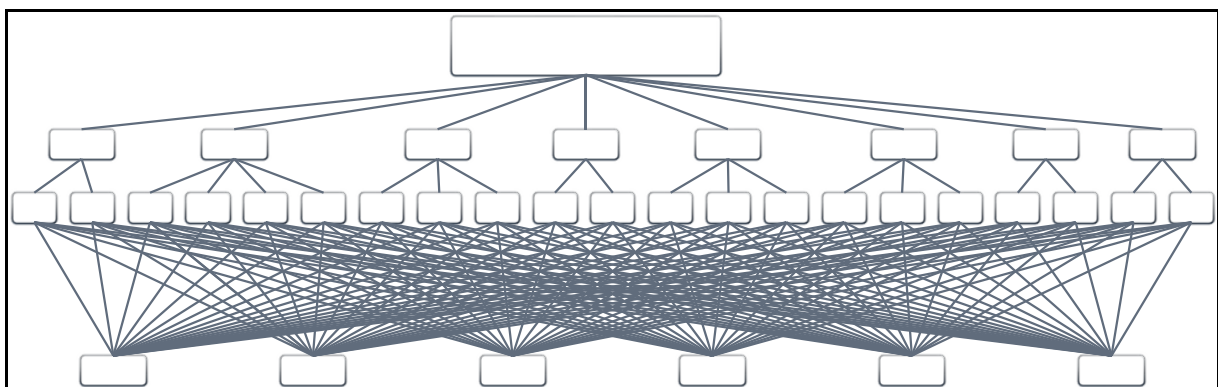*Step 2:* Constructing hierarchical structure. It is shown in Figure 1.

Figure 1. Hierarchical structure for LMS evaluation

Step 3: Application of Fuzzy AHP. The calculations of fuzzy AHP are made in Microsoft Excel program. Only basic calculations are shown in this article. Linguistic variables and triangular fuzzy numbers for the evaluation were shown in Table 1.

Step 4: Application of Fuzzy TOPSIS. Linguistic terms and triangular fuzzy numbers used in Fuzzy TOPSIS have shown in Table 2 and Table 3.

Step 5: Application of Integrated Method. The criteria weights obtained by Fuzzy AHP are used during alternative ranking by Fuzzy TOPSIS.

Step 6: Comparing methods.

Application of Fuzzy AHP

As mentioned before, Chang's gradual Fuzzy AHP method is explained in study of Kahraman et al. (2004) and is used for this study.

Step 1: Constructing fuzzy pair wise comparison matrix. According to five expert's judgments for criteria, fuzzy pair wise comparison matrix is established. The comparison values, obtained by pair-wise comparison matrices are converted into a single value with geometric mean. These values are shown in Table 6.

Table 6. Fuzzy pair wise comparison matrix for main criteria

	C_1			C_2			C_3			C_4		
	L	M	U	L	M	U	L	M	U	L	M	U
C_1	1.000	1.000	1.000	0.491	0.714	1.185	0.148	0.204	0.394	0.204	0.301	0.509
C_2	0.844	1.401	2.036	1.000	1.000	1.000	0.158	0.238	0.525	1.380	2.853	4.076
C_3	2.537	4.904	6.766	1.904	4.210	6.325	1.000	1.000	1.000	4.146	6.534	8.002
C_4	1.966	3.323	4.904	0.245	0.351	0.725	0.117	0.125	0.169	1.000	1.000	1.000
C_5	1.070	1.552	2.141	0.200	0.333	1.000	0.138	0.184	0.316	1.403	1.933	2.709
C_6	0.644	1.632	2.627	0.356	0.467	0.803	0.415	0.509	0.678	2.809	4.004	5.800
C_7	2.627	4.988	7.114	0.258	0.375	0.803	0.415	0.536	0.725	1.807	2.809	4.004
C_8	0.129	0.166	0.254	0.158	0.226	0.491	0.158	0.226	0.491	1.838	2.627	3.380
	C_5			C_6			C_7			C_8		
C_1	0.467	0.644	0.935	0.178	0.268	0.678	0.141	0.200	0.381	3.936	6.015	7.740
C_2	1.380	3.554	5.624	1.246	2.141	2.809	1.246	2.667	3.876	1.476	3.737	5.624
C_3	3.160	5.431	7.237	1.476	1.963	2.408	1.380	1.867	2.408	2.809	5.245	7.114
C_4	0.369	0.517	0.713	0.172	0.250	0.356	0.250	0.356	0.553	0.296	0.381	0.544
C_5	1.000	1.000	1.000	0.725	1.125	1.719	0.296	0.422	0.725	0.422	0.602	1.070
C_6	0.582	0.889	1.380	1.000	1.000	1.000	1.810	2.290	2.709	1.719	3.936	6.015
C_7	1.719	2.627	3.615	0.369	0.437	0.552	1.000	1.000	1.000	3.680	5.720	7.740
C_8	0.935	2.068	3.272	0.166	0.254	0.582	0.250	0.356	0.553	1.000	1.000	1.000

L: Low, M: Medium, U: Upper.

Step 2: Checking the consistency of the comparison matrix. The fuzzy numbers should be firstly converted into matching crisp values for the following equation;

$$\frac{l+4m+u}{6} \tag{1}$$

The consistency process is made according to study of Zheng et al. (2012) and it is seen that the comparison matrix is consistent.

Step 3: The value of fuzzy synthetic extent is defined as; SC1= (0.042, 0.084, 0.0185), SC2=(0.056, 0.158, 0.369), SC3= (0.118, 0.279, 0.569), SC4=(0.028, 0.056, 0.129), SC5= (0.034, 0.064, 0.0154), SC6=(0.060, 0.132, 0.304), SC 7= (0.076, 0.166, 0.369), SC 8=(0.030, 0.062, 0.145).

After applying other steps the weight vector for main criteria is obtained as;

$$W = (0.074, 0.194, 0.287, 0.014, 0.041, 0.0161, 0.198, 0.031)^T$$

The same calculations are made for sub criteria and the weight vector for sub criteria is as following;

$$W = \begin{pmatrix} 0.425, 0.575, 0.417, 0.057, 0.352, 0.174, 0.324, 0.253, 0.423, 0.559, \\ 0.441, 0.220, 0.401, 0.379, 0.220, 0.222, 0.469, 0.441, 0.559 \end{pmatrix}^T$$

Then, pair-wise comparisons of alternatives according to sub-criteria are made. The alternative values according to sub-criteria are shown in Table 7. By multiplying the values in Table 6 and sub criteria weight vector, Table 8 is obtained. By multiplying the values in Table 7 and main criteria weight vector, Table 9 is obtained.

Table 7. Alternative weights based on sub-criteria

	C_{11}	C_{12}	C_{21}	C_{22}	C_{23}	C_{24}	C_{31}
A1	0.225	0.216	0.293	0.268	0.241	0.217	0.212
A2	0.235	0.223	0.227	0.208	0.226	0.257	0.276
A3	0.033	0.000	0.000	0.000	0.000	0.000	0.000
A4	0.467	0.445	0.429	0.300	0.418	0.266	0.325
A5	0.000	0.000	0.000	0.000	0.000	0.099	0.000
A6	0.040	0.116	0.052	0.224	0.116	0.166	0.159
	C_{32}	C_{33}	C_{41}	C_{42}	C_{51}	C_{52}	C_{53}
A1	0.239	0.235	0.225	0.256	0.256	0.288	0.202
A2	0.276	0.242	0.243	0.266	0.201	0.227	0.233
A3	0.000	0.000	0.000	0.069	0.000	0.000	0.000
A4	0.325	0.329	0.352	0.364	0.325	0.338	0.352
A5	0.000	0.013	0.087	0.000	0.048	0.000	0.018
A6	0.159	0.181	0.093	0.045	0.170	0.146	0.195

	C_{61}	C_{62}	C_{63}	C_{71}	C_{72}	C_{81}	C_{82}
A1	0.242	0.248	0.221	0.221	0.213	0.223	0.202
A2	0.217	0.220	0.229	0.229	0.228	0.189	0.241
A3	0.000	0.000	0.000	0.000	0.000	0.050	0.035
A4	0.337	0.387	0.357	0.357	0.345	0.392	0.391
A5	0.018	0.000	0.000	0.000	0.021	0.000	0.000
A6	0.187	0.144	0.192	0.192	0.193	0.145	0.131

Table 8. Alternative weights based on main criteria

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
A1	0.220	0.260	0.229	0.239	0.248	0.234	0.217	0.211
A2	0.228	0.231	0.262	0.253	0.223	0.223	0.228	0.219
A3	0.014	0.000	0.000	0.030	0.000	0.000	0.000	0.042
A4	0.455	0.389	0.327	0.357	0.341	0.358	0.351	0.391
A5	0.000	0.017	0.005	0.049	0.017	0.005	0.012	0.000
A6	0.084	0.104	0.168	0.072	0.170	0.180	0.193	0.137

Table 9. Importance weights of alternatives

Code	Alternative	Weight
A1	Atutor	0.233
A2	Claroline	0.237
A3	Sakai	0.004
A4	Moodle	0.363
A5	Olat	0.009
A6	Dokeos	0.154

Thus, based on Table 9, we infer that the alternative A4 is the optimal. The ranking order of the alternatives is given as A4>A2>A1>A6>A5>A3.

Application of Fuzzy TOPSIS

Step 1: Determining importance weights; the importance weights of each criteria are given by the five decision-makers as linguistic variables. The fuzzy weights of criteria are shown in Tables 10 and Table 11.

Table 10. The main criteria fuzzy importance weights

	L	M	U
C_1	0.260	0.460	0.660
C_2	0.740	0.920	1.000
C_3	0.860	0.980	1.000
C_4	0.140	0.340	0.540
C_5	0.500	0.700	0.900
C_6	0.700	0.900	1.000
C_7	0.740	0.920	1.000
C_8	0.060	0.220	0.420

Table 11. Sub-criteria fuzzy importance weights

	L	M	U		L	M	U
C_{11}	0.260	0.460	0.660	C_{51}	0.460	0.660	0.860
C_{12}	0.420	0.620	0.820	C_{52}	0.620	0.820	0.960
C_{21}	0.780	0.940	1.000	C_{53}	0.660	0.860	0.980
C_{22}	0.620	0.820	0.960	C_{61}	0.700	0.900	1.000
C_{23}	0.740	0.920	1.000	C_{62}	0.700	0.900	1.000
C_{24}	0.700	0.900	1.000	C_{63}	0.780	0.940	1.000
C_{31}	0.740	0.920	1.000	C_{71}	0.780	0.940	1.000
C_{32}	0.660	0.860	0.980	C_{72}	0.740	0.920	1.000
C_{33}	0.860	0.980	1.000	C_{81}	0.780	0.940	1.000
C_{41}	0.180	0.380	0.580	C_{82}	0.260	0.460	0.660
C_{42}	0.220	0.420	0.620				

Step 2: Determining performance ratings; the performance ratings for the 6 alternatives are provided based on 21 sub-criteria by the five decision makers.

Step 3: Constructing normalized fuzzy decision matrix. The normalized fuzzy decision matrix is presented in Table 5 in the Appendix.

Step 4: Constructing weighted normalized fuzzy decision matrix. By multiplying Table 10 and Table 5 in the Appendix, the weighted normalized fuzzy decision matrix is obtained and given in Table 6 in the Appendix.

Step 5: Determining the ideal (I+) and anti-ideal (I-) solution for each alternative. Table 12 presents the distance of each alternative from (I+) and (I-).

Table 12. Distance of each concept from ideal and anti-ideal solutions and closeness index

Alternative Code	d_i^-	d_i^+	Closeness Index
A1	13.960	8.893	0.611
A2	13.650	9.219	0.597
A3	2.176	19.276	0.101
A4	15.245	7.371	0.674
A5	3.674	18.061	0.169
A6	6.804	15.405	0.306

Step 6: Calculating closeness coefficient. Table 12 presents the closeness index of each alternative.

Thus, based on the values of the closeness index, we infer that the alternative A4 is the optimal one. The ranking order of the alternatives is given as A4>A1>A2>A6>A5>A3.

Integrated Fuzzy AHP-TOPSIS Application

Stages of the integrated approach are shown in Figure 2. The criteria value, obtained by Fuzzy AHP is used when ranking alternatives by Fuzzy TOPSIS.
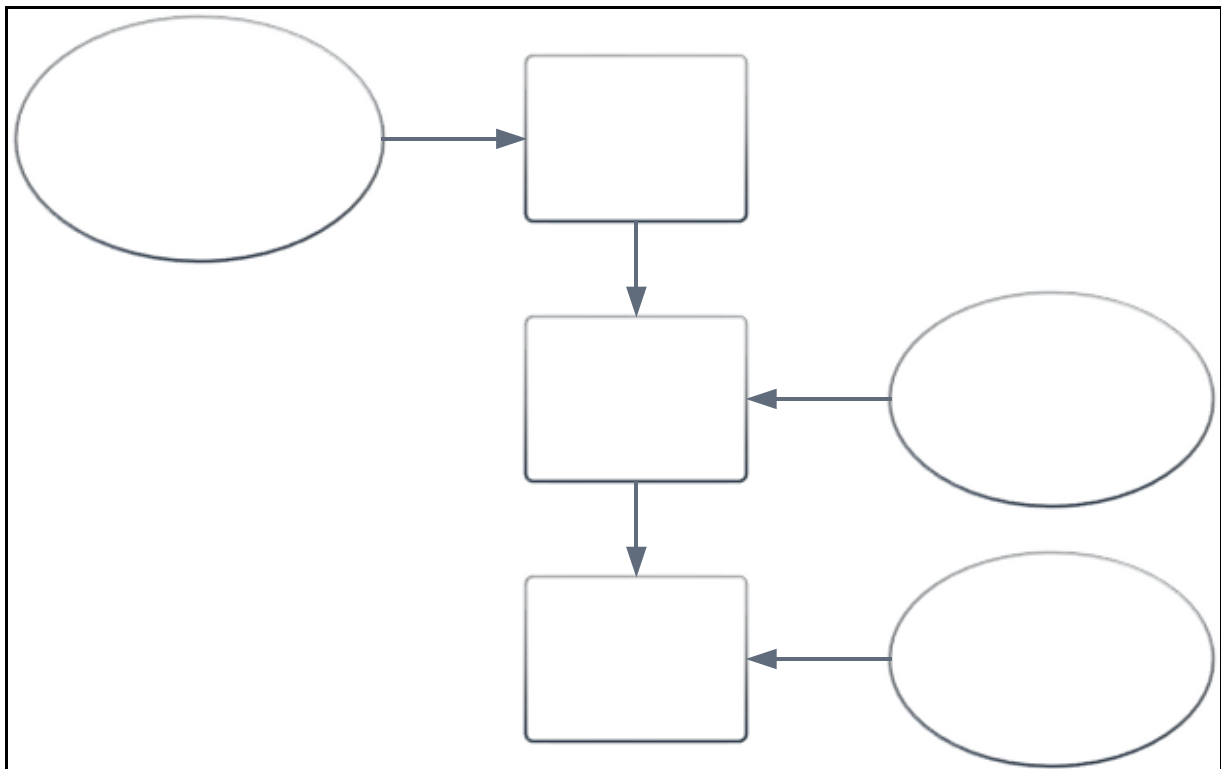

Figure 2. Stages of integrated method

Step 1: Determining criteria importance weights. The criteria value, obtained by Fuzzy AHP is used.

Step 2: Determining performance ratings as shown in Fuzzy TOPSIS application.

Step 3: Constructing normalized fuzzy decision matrix. The normalized fuzzy decision matrix, obtained in Fuzzy TOPSIS is used.

Step 4: Constructing weighted normalized fuzzy decision matrix. By multiplying sub-criteria values are obtained by Fuzzy AHP and normalized fuzzy decision matrix, weighted normalized fuzzy decision matrix is obtained and given in Table 7 in the Appendix.

Step 5: Determining the ideal (I+) and anti-ideal (I-) solution for each alternative. Table 13 presents the distance of each alternative from (I+) and (I-).

Table 13. Distance of each concept from ideal and anti-ideal solutions and closeness Index

Alternative Code	d_i^-	d_i^+	Closeness Index
A1	6.692	14.433	0.317
A2	6.545	14.594	0.310
A3	0.918	20.235	0.043
A4	7.477	13.564	0.355
A5	1.663	19.567	0.078
A6	2.819	18.461	0.132

Step 6: Calculating closeness coefficient. Table 13 presents the closeness index of each alternative.
Thus, based on the values of the closeness index, we infer that the alternative A4 is the optimal one. The ranking order of the alternatives is given as A4>A1>A2>A6>A5>A3.

Comparing Methods
Tables 14 and Table 15 show criteria of values, obtained from Fuzzy AHP and Fuzzy TOPSIS respectively. The fuzzy numbers, obtained from Fuzzy TOPSIS are defuzzificated. Thus, an easier evaluation process is provided.

Table 14. Criteria weights for Fuzzy AHP

Main Criteria	Weight	Sub-criteria	Weight
Ease of Use	0.074	C_{11}: Friendly Interface	0.425
		C_{12}: Flexible Systems	0.575
Communication, Interaction and Cooperation	0.194	C_{21}: Discussion / Forum	0.417
		C_{22}: Whiteboard	0.057
		C_{23}: Video Conferencing support	0.352
		C_{24}: Social networking	0.174

Content Management and Development	0.287	C_{31}: Compliance with Teaching Standards	0.324
		C_{32}: Content sharing tools	0.253
		C_{33}: Course templates	0.423
Support	0.014	C_{41}: Online help	0.559
		C_{42}: Educational support	0.441
Productivity Tools	0.041	C_{51}: Calendar	0.220
		C_{52}: Searching Engine	0.401
		C_{53}: Help tool	0.379
Measuring Tools	0.161	C_{61}: Test / exam tools	0.309
		C_{62}: Question bank management	0.222
		C_{63}: Automated test management	0.469
Evaluation Tools	0.198	C_{71}: Student Tracking	0.441
		C_{72}: Courses / training management	0.559
Security	0.031	C_{81}: Authentication	0.441
		C_{82}: The frequency of publication of Security Patch	0.559

Table 15. Criteria weights for Fuzzy TOPSIS

Main Criteria	Weight	Sub-criteria	Weight
Ease of Use	0.460	C_{11}: Friendly Interface	0.460
		C_{12}: Flexible Systems	0.620
Communication, Interaction and Cooperation	0.903	C_{21}: Discussion / Forum	0.923
		C_{22}: Whiteboard	0.810
		C_{23}: Video Conferencing support	0.903
		C_{24}: Social networking	0.883
Content Management and Development	0.963	C_{31}: Compliance with Teaching Standards	0.903
		C_{32}: Content sharing tools	0.847
		C_{33}: Course templates	0.963
Support	0.340	C_{41}: Online help	0.380
		C_{42}: Educational support	0.420
Productivity Tools	0.700	C_{51}: Calendar	0.660
		C_{52}: Searching Engine	0.810

		C$_{53}$: Help tool	0.847
Measuring Tools	0.883	C$_{61}$: Test / exam tools	0.883
		C$_{62}$: Question bank management	0.883
		C$_{63}$: Automated test management	0.923
Evaluation Tools	0.903	C$_{71}$: Student Tracking	0.903
		C$_{72}$: Courses / training management	0.923
Security	0.227	C$_{81}$: Authentication	0.460
		C$_{82}$: The frequency of publication of Security Patch	0.460

As seen at Table 14, Content Management and Development is the most important criteria with the 28.7% value. It is seen that Evaluation Tools and Communication, Interaction and Cooperation has almost equal importance with 19.8% and 19.4% value. Measuring Tools (16.0%), Ease of Use (7.4%), Productivity Tools (4.1%), Security (3.1%) and Support (1.6%) followed them.

Course templates are the most important ones between sub criteria of Content Management and Development. It is seen that Discussion / Forum is the most important criteria between sub criteria of Communication, Interaction and Cooperation. Courses / Training Management and Student Tracking have almost equal importance. Automated test management is more important than the other sub criteria of Measuring Tools. It is observed that Ease of Use and Security has almost equal importance. Searching Engine and Online Help is respectively the most important criteria between sub criteria of Productivity Tools and Support.

As seen at Table 15, the ranking is like that; Content Management and Development (96.3%) has seen as the first criteria. With the equal importance of Evaluation Tools (90.3%) and Communication, Interaction and Cooperation (90.3%) is second order. Measuring Tools (88.3%), Productivity Tools (70.0%), Ease of Use (46.6%), Support (34.0%), and Security (22.7%) follows them respectively. The criteria ranking, obtained from Fuzzy AHP and Fuzzy TOPSIS shows a little difference from each other.

Table 16. Alternative importance weights and rankings

Alternative	Fuzzy AHP		Fuzzy TOPSIS		Integrated Method	
	Weight	Ranking	Closeness Index	Ranking	Closeness Index	Ranking
Atutor	0.233	3	0.611	2	0.317	2
Claroline	0.237	2	0.597	3	0.310	3
Sakai	0.004	6	0.101	6	0.043	6
Moodle	0.363	1	0.674	1	0.355	1
Olat	0.009	5	0.169	5	0.078	5
Dokeos	0.154	4	0.306	4	0.132	4

As seen at Table 16, Moodle is the best alternative with the degree of 36.3%. The second and third LMS are Claroline and Atutor with the degree of 23.3% and 23.7%. The fourth is Dokeos (15.4%) and the last

two LMS are Olat (0.09%) and Sakai (0.04%) and it is seen that these two alternatives remained quite inadequate in terms of meeting the criteria. Analyzing the results of Fuzzy TOPSIS and integrated methods, it is seen only the ranking of Moodle and Atutor changed, others have the same ranking. Only the closeness indexes differ from each other because of the linguistics variable, used in Fuzzy AHP, it is smaller than used TOPSIS.

The results are adaptable with literature. As we talk about Sec. 2 the Moodle emerges the most preferred system between alternatives. The criteria especially the main criteria are almost the same as discussed in the literature. Differ from the others, we found the importance weight of these criteria.

CONCLUSION

With the development of technology, distance education has become an important role in teaching and learning and it is actively used almost in every developed or developing countries. Therefore, requirement for systems served e-learning increase day by day. These systems called LMS and every system has different features. In this study, we want to guide universities and educational organizations for selection LMS and show criteria importance weights for LMS evaluation.

We used fuzzy MCDM techniques to define important criteria and to select the best alternative. AHP and TOPSIS reflect the opinion of experts. But, traditional techniques do not clearly express human thoughts. Decision makers are unwilling to make certain judgments so; they prefer discrete values rather than exact values to reflect the human thoughts. Because of this, the fuzzy AHP and fuzzy TOPSIS are used in this study. An integrated method for obtaining more certain results are made too. The criteria weights obtained by Fuzzy AHP are used during alternative ranking by Fuzzy TOPSIS in integrated method.

After evaluating criteria with three methods, Content Management and Development has emerged as the most important criteria. In the same way Moodle, emerged as the best alternative, can be selected in all methods. And also it can be seen that Moodle is easily preferred by many institutions in Turkey. So it can be said that these results seem to be logical and consistent.

According to these results the superiority of these methods to each other or weak point that is relative to one another cannot be criticized. This study showed these three methods can be easily used in the selection of LMS process.

For future studies, the well-known MCDM techniques such as ANP (Analytic Network Process), VIKOR (VlseKriterijumska Optimizacija I Kompromisno Resenje), PROMETHEE (Preference Ranking Organization METHod for Enrichment Evaluation) and etc. can be used for evaluation and selection of LMS. Furthermore, the criteria used in this study are obtained by expert opinions and literature review. There are a quite number of criteria and these criteria can be defined as dependent and independent criteria. In this respect, DEMATEL (The Decision Making Trial and Evaluation Laboratory Method) method can be employed to determine important evaluation main criteria and sub-criteria.

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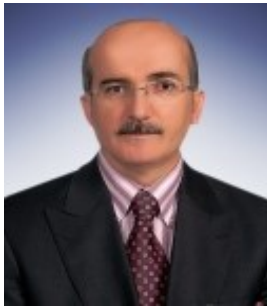
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APPENDIX

Table 1. Main criteria evaluation form for Fuzzy AHP

Main Criteria		C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
C_1	Ease of Use								
C_2	Communication, Interaction and Cooperation								
C_3	Content Management and Development								
C_4	Support								
C_5	Productivity Tools								
C_6	Measuring Tools								
C_7	Evaluation Tools								
C_8	Security								

Table 2. Sub-criteria evaluation form for Fuzzy AHP

Sub-criteria		C_{11}	C_{12}	C_{21}	C_{22}	C_{23}	C_{24}	C_{31}	C_{32}	C_{33}	C_{41}	C_{42}	C_{51}	C_{52}	C_{53}	C_{61}	C_{62}	C_{63}	C_{71}	C_{72}	C_{81}	C_{82}
C_{11}	Friendly interface																					
C_{12}	Flexible systems																					

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Code	Item																			
C_{21}	Discussion / forum		▓																	
C_{22}	Whiteboard			▓																
C_{23}	Video conferencing support				▓															
C_{24}	Social networking					▓														
C_{31}	Compliance with teaching standards						▓													
C_{32}	Content sharing tools							▓												
C_{33}	Course templates								▓											
C_{41}	Online help									▓										
C_{42}	Educational support										▓									
C_{51}	Calendar											▓								
C_{52}	Searching engine												▓							
C_{53}	Help tool													▓						
C_{61}	Test / Exam tools														▓					
C_{62}	Question bank management															▓				
C_{63}	Automated test management																▓			
C_{71}	Student tracking																	▓		
C_{72}	Courses / training management																		▓	
C_{81}	Authentication																			▓
C_{82}	The frequency of publication of security patch																			▓

Table 3. Main criteria evaluation form for Fuzzy TOPSIS

	Main Criteria	Very High	High	Medium High	Medium	Medium Low	Low	Very Low
C_1	Ease of Use							
C_2	Communication, Interaction and Cooperation							
C_3	Content Management and Development							
C_4	Support							
C_5	Productivity Tools							
C_6	Measuring Tools							
C_7	Evaluation Tools							
C_8	Security							

Table 4. Sub-criteria evaluation form for Fuzzy TOPSIS

		Very High	High	Medium High	Medium	Medium Low	Low	Very Low
C_{11}	Friendly interface							
C_{12}	Flexible systems							
C_{21}	Discussion / forum							
C_{22}	Whiteboard							
C_{23}	Video conferencing support							
C_{24}	Social networking							
C_{31}	Compliance with teaching standards							
C_{32}	Content sharing tools							
C_{33}	Course templates							
C_{41}	Online help							
C_{42}	Educational support							
C_{51}	Calendar							
C_{52}	Searching engine							
C_{53}	Help tool							
C_{61}	Test / Exam tools							
C_{62}	Question bank management							

C_{63}	Automated test management							
C_{71}	Student tracking							
C_{72}	Courses / training management							
C_{81}	Authentication							
C_{82}	The frequency of publication of security patch							

Table 5. Normalized fuzzy decision matrix for FAHP

	C_{11}	C_{12}	C_{21}	C_{22}	C_{23}	C_{24}	C_{31}
A1	0.580 0.780 0.940	0.620 0.820 0.960	0.660 0.860 0.980	0.660 0.860 0.980	0.620 0.820 0.960	0.620 0.820 0.960	0.660 0.860 0.980
A2	0.500 0.700 0.880	0.580 0.780 0.940	0.620 0.820 0.960	0.420 0.620 0.820	0.620 0.820 0.960	0.620 0.820 0.960	0.780 0.940 1.000
A3	0.020 0.120 0.180	0.020 0.120 0.180	0.020 0.100 0.180	0.020 0.140 0.180	0.020 0.140 0.180	0.080 0.260 0.420	0.080 0.260 0.420
A4	0.820 0.960 1.000	0.820 0.960 1.000	0.900 1.000 1.000	0.860 0.980 1.000	0.860 0.980 1.000	0.820 0.960 1.000	0.820 0.960 1.000
A5	0.060 0.220 0.340	0.060 0.220 0.340	0.020 0.120 0.180	0.060 0.220 0.340	0.020 0.120 0.180	0.060 0.220 0.340	0.180 0.380 0.580
A6	0.140 0.340 0.540	0.180 0.380 0.580	0.040 0.180 0.260	0.500 0.700 0.880	0.220 0.420 0.620	0.220 0.420 0.620	0.300 0.500 0.700

	C_{32}	C_{33}	C_{41}	C_{42}	C_{51}	C_{52}	C_{53}
A1	0.520 0.680 0.780	0.620 0.820 0.960	0.620 0.820 0.940	0.660 0.840 0.940	0.660 0.840 0.940	0.780 0.940 1.000	0.660 0.860 0.980
A2	0.660 0.860 0.980	0.660 0.860 0.980	0.620 0.820 0.940	0.660 0.840 0.940	0.540 0.740 0.880	0.620 0.820 0.940	0.620 0.820 0.960
A3	0.040 0.180 0.260	0.020 0.140 0.180	0.040 0.180 0.260	0.000 0.080 0.100	0.000 0.040 0.100	0.000 0.060 0.100	0.000 0.060 0.100
A4	0.860 0.980 1.000	0.780 0.940 1.000	0.820 0.960 1.000	0.860 0.980 1.000	0.780 0.940 1.000	0.820 0.960 1.000	0.860 0.980 1.000
A5	0.000 0.080 0.100	0.060 0.220 0.340	0.140 0.340 0.540	0.000 0.060 0.100	0.080 0.260 0.420	0.040 0.180 0.260	0.060 0.220 0.340
A6	0.220 0.420 0.620	0.180 0.380 0.580	0.180 0.380 0.580	0.020 0.140 0.180	0.220 0.420 0.620	0.140 0.340 0.540	0.220 0.420 0.620

	C_{61}	C_{62}	C_{63}	C_{71}	C_{72}	C_{81}	C_{82}
A1	0.700 0.900 1.000	0.740 0.920 1.000	0.740 0.920 1.000	0.700 0.900 1.000	0.660 0.860 0.980	0.700 0.900 1.000	0.660 0.860 0.980
A2	0.580 0.780 0.940	0.660 0.860 0.980	0.660 0.860 0.980	0.740 0.920 1.000	0.700 0.900 1.000	0.580 0.780 0.940	0.660 0.860 0.980
A3	0.000 0.080 0.100	0.000 0.060 0.100	0.000 0.060 0.100	0.000 0.060 0.100	0.000 0.060 0.100	0.020 0.140 0.180	0.000 0.100 0.100
A4	0.780 0.940 1.000	0.820 0.960 1.000	0.780 0.940 1.000	0.780 0.940 1.000	0.860 0.980 1.000	0.860 0.980 1.000	0.860 0.980 1.000
A5	0.060 0.220 0.340	0.020 0.140 0.180	0.060 0.220 0.340	0.000 0.060 0.100	0.060 0.220 0.340	0.040 0.180 0.260	0.040 0.160 0.260
A6	0.180 0.380 0.580	0.060 0.220 0.340	0.160 0.340 0.500	0.160 0.340 0.500	0.120 0.300 0.460	0.060 0.220 0.340	0.040 0.180 0.260

Table 6. Weighted normalized fuzzy decision matrix for TOPSIS

	C_{11}	C_{12}	C_{21}	C_{22}	C_{23}	C_{24}	C_{31}
A1	0.151 0.359 0.620	0.260 0.508 0.787	0.515 0.808 0.980	0.409 0.705 0.941	0.459 0.754 0.960	0.434 0.738 0.960	0.488 0.791 0.980
A2	0.130 0.322 0.581	0.244 0.484 0.771	0.484 0.771 0.960	0.260 0.508 0.787	0.459 0.754 0.960	0.434 0.738 0.960	0.577 0.865 1.000
A3	0.005 0.055 0.119	0.008 0.074 0.148	0.016 0.094 0.180	0.012 0.115 0.173	0.015 0.129 0.180	0.056 0.234 0.420	0.059 0.239 0.420
A4	0.213 0.442 0.660	0.344 0.595 0.820	0.702 0.940 1.000	0.533 0.804 0.960	0.636 0.902 1.000	0.574 0.864 1.000	0.607 0.883 1.000
A5	0.016 0.101 0.224	0.025 0.136 0.279	0.016 0.113 0.180	0.037 0.180 0.326	0.015 0.110 0.180	0.042 0.198 0.340	0.133 0.350 0.580
A6	0.036 0.156 0.356	0.076 0.236 0.476	0.031 0.169 0.260	0.310 0.574 0.845	0.163 0.386 0.620	0.154 0.378 0.620	0.222 0.460 0.700

	C_{32}	C_{33}	C_{41}	C_{42}	C_{51}	C_{52}	C_{53}
A1	0.343 0.585 0.764	0.533 0.804 0.960	0.112 0.312 0.545	0.145 0.353 0.583	0.304 0.554 0.808	0.484 0.771 0.960	0.436 0.740 0.960
A2	0.436 0.740 0.960	0.568 0.843 0.980	0.112 0.312 0.545	0.145 0.353 0.583	0.248 0.488 0.757	0.384 0.672 0.902	0.409 0.705 0.941
A3	0.026 0.155 0.255	0.017 0.137 0.180	0.007 0.068 0.151	0.000 0.034 0.062	0.000 0.026 0.086	0.000 0.049 0.096	0.000 0.052 0.098
A4	0.568 0.843 0.980	0.671 0.921 1.000	0.148 0.365 0.580	0.189 0.412 0.620	0.359 0.620 0.860	0.508 0.787 0.960	0.568 0.843 0.980
A5	0.000 0.069 0.098	0.052 0.216 0.340	0.025 0.129 0.313	0.000 0.025 0.062	0.037 0.172 0.361	0.025 0.148 0.250	0.040 0.189 0.333
A6	0.145 0.361 0.608	0.155 0.372 0.580	0.032 0.144 0.336	0.004 0.059 0.112	0.101 0.277 0.533	0.087 0.279 0.518	0.145 0.361 0.608

	C_{61}	C_{62}	C_{63}	C_{71}	C_{72}	C_{81}	C_{82}
A1	0.490 0.810 1.000	0.518 0.828 1.000	0.577 0.865 1.000	0.518 0.828 1.000	0.515 0.808 0.980	0.182 0.414 0.660	0.172 0.396 0.647
A2	0.406 0.702 0.940	0.462 0.774 0.980	0.515 0.808 0.980	0.548 0.846 1.000	0.546 0.846 1.000	0.151 0.359 0.620	0.172 0.396 0.647
A3	0.000 0.072 0.100	0.000 0.054 0.100	0.000 0.056 0.100	0.000 0.055 0.100	0.000 0.056 0.100	0.005 0.064 0.119	0.000 0.046 0.066
A4	0.546 0.846 1.000	0.574 0.864 1.000	0.608 0.884 1.000	0.577 0.865 1.000	0.671 0.921 1.000	0.224 0.451 0.660	0.224 0.451 0.660
A5	0.042 0.198 0.340	0.014 0.126 0.180	0.047 0.207 0.340	0.000 0.055 0.100	0.047 0.207 0.340	0.010 0.083 0.172	0.010 0.074 0.172
A6	0.126 0.342 0.580	0.042 0.198 0.340	0.125 0.320 0.500	0.118 0.313 0.500	0.094 0.282 0.460	0.016 0.101 0.224	0.010 0.083 0.172

Table 7. Weighted normalized fuzzy decision matrix for integrated method

	C$_{11}$	C$_{12}$	C$_{21}$	C$_{22}$	C$_{23}$	C$_{24}$	C$_{31}$
A1	0.247 0.332 0.400	0.357 0.472 0.552	0.275 0.359 0.409	0.038 0.049 0.056	0.218 0.289 0.338	0.107 0.142 0.166	0.214 0.279 0.318
A2	0.213 0.298 0.374	0.334 0.449 0.541	0.259 0.342 0.400	0.024 0.035 0.047	0.218 0.289 0.338	0.107 0.142 0.166	0.253 0.305 0.324
A3	0.009 0.051 0.077	0.012 0.069 0.104	0.008 0.042 0.075	0.001 0.008 0.010	0.007 0.049 0.063	0.014 0.045 0.073	0.026 0.084 0.136
A4	0.349 0.408 0.425	0.472 0.552 0.575	0.375 0.417 0.417	0.049 0.056 0.057	0.303 0.345 0.352	0.142 0.166 0.173	0.266 0.311 0.324
A5	0.026 0.094 0.145	0.035 0.127 0.196	0.008 0.050 0.075	0.003 0.013 0.019	0.007 0.042 0.063	0.010 0.038 0.059	0.058 0.123 0.188
A6	0.060 0.145 0.230	0.104 0.219 0.334	0.017 0.075 0.108	0.029 0.040 0.050	0.077 0.148 0.218	0.038 0.073 0.107	0.097 0.162 0.227

	C$_{32}$	C$_{33}$	C$_{41}$	C$_{42}$	C$_{51}$	C$_{52}$	C$_{53}$
A1	0.132 0.172 0.197	0.262 0.347 0.406	0.347 0.458 0.525	0.291 0.370 0.415	0.145 0.185 0.207	0.313 0.377 0.401	0.250 0.326 0.371
A2	0.167 0.218 0.248	0.279 0.364 0.415	0.347 0.458 0.525	0.291 0.370 0.415	0.119 0.163 0.194	0.249 0.329 0.377	0.235 0.311 0.364
A3	0.010 0.046 0.066	0.008 0.059 0.076	0.022 0.101 0.145	0.000 0.035 0.044	0.000 0.009 0.022	0.000 0.024 0.040	0.000 0.023 0.038
A4	0.218 0.248 0.253	0.330 0.398 0.423	0.458 0.537 0.559	0.379 0.432 0.441	0.172 0.207 0.220	0.329 0.385 0.401	0.326 0.371 0.379
A5	0.000 0.020 0.025	0.025 0.093 0.144	0.078 0.190 0.302	0.000 0.026 0.044	0.018 0.057 0.092	0.016 0.072 0.104	0.023 0.083 0.129
A6	0.056 0.106 0.157	0.076 0.161 0.245	0.101 0.212 0.324	0.009 0.062 0.079	0.048 0.092 0.136	0.056 0.136 0.217	0.083 0.159 0.235

	C$_{61}$	C$_{62}$	C$_{63}$	C$_{71}$	C$_{72}$	C$_{81}$	C$_{82}$
A1	0.216 0.278 0.309	0.164 0.204 0.222	0.347 0.431 0.469	0.309 0.397 0.441	0.369 0.481 0.548	0.309 0.397 0.441	0.369 0.481 0.548
A2	0.179 0.241 0.290	0.147 0.191 0.218	0.310 0.403 0.460	0.326 0.406 0.441	0.391 0.503 0.559	0.256 0.344 0.415	0.369 0.481 0.548
A3	0.000 0.025 0.031	0.000 0.013 0.022	0.000 0.028 0.047	0.000 0.026 0.044	0.000 0.034 0.056	0.009 0.062 0.079	0.000 0.056 0.056
A4	0.241 0.290 0.309	0.182 0.213 0.222	0.366 0.441 0.469	0.344 0.415 0.441	0.481 0.548 0.559	0.379 0.432 0.441	0.481 0.548 0.559
A5	0.019 0.068 0.105	0.004 0.031 0.040	0.028 0.103 0.159	0.000 0.026 0.044	0.034 0.123 0.190	0.018 0.079 0.115	0.022 0.089 0.145
A6	0.056 0.117 0.179	0.013 0.049 0.075	0.075 0.159 0.235	0.071 0.150 0.221	0.067 0.168 0.257	0.026 0.097 0.150	0.022 0.101 0.145