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- İşletme / Araştırma -

Determination Of Elective Course Based On Hierarchical Fuzzy Topsis Method With Matlab Software

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ABSTRACT

The determination of elective course in undergraduate education is an important decision making process, because the course chosen allows the students to specialize in the area they are interested in. The aim of this study is to apply Hierarchical Fuzzy TOPSIS (HFTOPSIS) method in determining elective course as a fuzzy multi-criteria decision making (FMCDM) technique and introduce the programme developed in MATLAB software related to this decision making process. In this study, a decision model based on the process of determining elective course belonging to the sixth semester of third year students receiving education in economics department at a state university is developed. The assessments of the importance weights of the main and sub-criteria used in determining elective course and the assessments of the elective courses opened in the sixth semester in terms of the sub-criteria are performed by using linguistic variables. Then, these linguistic data are transformed into triangular fuzzy numbers, used in two different algorithms of HFTOPSIS and, relevant process is programmed, and the results of the two algorithms are compared. In the study it is concluded that the most important decision criteria for determining the elective course is elements relating to the lecturer (0.76, 0.96, 1.00). According to the two algorithms, the candidate elective courses are ranked from the best to the worst with respect to the calculated closeness coefficients. The ranking order of three alternative elective courses is similar according to the two approaches handled in the study, and it is as $A_1 > A_3 > A_2$. It is seen that the most appropriate elective course is A_1 with a closeness coefficient 0.821 according to the first approach and 0.819 according to the second approach. When the evaluation about whether the choice is risky or not via the closeness coefficient of elective course A_1 is made, it can be expressed that the alternative chosen is “approved and preferred”.

Keywords: Elective Course Determination, Fuzzy Multi-Criteria Decision Making, Hierarchical Fuzzy TOPSIS, Programming, MATLAB.

Matlab Yazılımıyla Hiyerarşik Bulanık TOPSIS Yöntemine Dayalı Seçmeli Dersin Belirlenmesi

ÖZ

Seçtikleri ders öğrencilerin ilgilendikleri alanda uzmanlaşmalarına imkan tanıdığı için lisans eğitiminde seçmeli dersin belirlenmesi önemli bir karar verme sürecidir. Bu çalışmanın amacı, seçmeli dersin belirlenmesine bulanık bir çok kriterli karar verme yöntemi olarak Hiyerarşik Bulanık TOPSIS (HBTOPSIS)'i uygulamak ve bu karar verme sürecine ilişkin MATLAB yazılımında geliştirilen programı tanıtmaktır. Bu çalışmada bir devlet üniversitesinin iktisat bölümünde eğitim gören üçüncü sınıf öğrencilerinin altıncı dönemine ilişkin seçmeli ders belirleme sürecine dayanan bir karar modeli geliştirilmiştir. İlgili öğrencilerin seçmeli ders belirlemesinde kullanılan ana ve alt kriterlerinin önem ağırlığının değerlendirilmesi ve altıncı dönemde açılan seçmeli derslerin alt kriterler yoluyla değerlendirilmesi dilsel değişkenlerle gerçekleştirilmiştir. Daha sonra, bu sözel veriler üçgen bulanık sayılara çevrilerek HBTOPSIS yöntemine ait iki farklı algoritma kullanılmış, ilgili süreç programlanmış ve iki algoritmanın sonuçları karşılaştırılmıştır. Çalışmada seçmeli dersin belirlenmesi için en önemli karar kriterinin öğretim elemanına ilişkin unsurlar (0.76, 0.96, 1.00) olduğu sonucuna ulaşılmıştır. Aday dersler her iki algoritmaya göre hesaplanan yakınlık katsayıları dikkate alınarak en iyiden en kötüye doğru sıralanmıştır. Üç alternatif dersin sıralaması çalışmada ele alınan iki yaklaşıma göre benzerlik göstermektedir ve $A_1 > A_3 > A_2$ şeklindedir. Birinci yaklaşıma göre 0.821, ikinci yaklaşıma göre 0.819 olan yakınlık katsayısıyla en uygun seçmeli dersin A_1 olduğu görülmüştür. A_1 seçmeli dersinin yakınlık katsayısı yoluyla seçimin risk içerip içermediği değerlendirildiğinde seçilen alternatifin “kabul edilebilir ve kesinlikle tercih edilebilir” olduğu ifade edilebilir.

Anahtar Kelimeler: Seçmeli Dersin Belirlenmesi, Bulanık Çok-Kriterli Karar Verme, Hiyerarşik Bulanık TOPSIS, Programlama, MATLAB.

1. Introduction

The determination of elective course in undergraduate education is an important decision making process, because the course chosen allows the students to specialize in the area they are interested in. Choosing the most suitable one among the alternative courses is a complex decision problem that needs to consider multi-criteria (Ersöz et al., 2011; 228). The important point in multi-criteria decision making (MCDM) is that there are incompatible criteria or attributes used for assessing alternatives (Özdemir and

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Deste, 2009; 147). In MCDM, solution can be achieved simultaneously by bringing together many criteria and alternative (Bülbül ve Köse, 2009; 1).

Because of that decision making is based on qualitative data more than quantitative (Li and Yang, 2004; 274) in recent years, fuzzy logic approach more suitable when analyzing these data has mostly begun to be preferred. It can be seen from the literature that hybrid forms of fuzzy logic and MCDM techniques are widely used in the studies.

In this study, the process of determinig elective course is handled with HFTOPSIS method. The aim of this study is introducing a programme developed in MATLAB software related to FMCDM model based on HFTOPSIS. For the application, as decision makers, five economics department students evaluate main and sub-criteria and the candidate elective courses by using linguistic variables. Then, these linguistic data is transformed into triangular fuzzy numbers, used in two different algorithms of HFTOPSIS and, relevant process is programmed, and the results of the two algorithms are compared. According to the two algorithms, the candidate elective courses are ranked from the best to the worst with respect to the calculated closeness coefficients.

HFTOPSIS method has been widely used in various studies in the literature. Ates et al. (2006) carried out the performance appraisal process of engineering faculty in a university with HFTOPSIS method. Kahraman et al. (2007b) applied HFTOPSIS method to the selection of electronic service provider. Kahraman et al. (2007c) used an integrated approach based on fuzzy heuristic multi-attribute utility method and HFTOPSIS method for new product decision making process of one of the biggest automobile producer of Turkey. Perçin (2008) preferred HFTOPSIS technique for determining which business process is the most appropriate one for outsourcing, while Kahraman et al. (2007a) used the same method for the selection problem of logistics information technologies. Tolga (2008) preferred HFTOPSIS method as methodology for deciding among six different Research and Development projects while Taghavifard and Mirheydari (2008) handled supplier selection problem of a steel company with HFTOPSIS method. While Bao et al. (2010) used HFTOPSIS in assessing 21 countries road safety performance, Taghavifard et al. (2011) handled technology transfer of medical equipment problem with HFTOPSIS. Paksoy et al. (2012) used fuzzy AHP and HFTOPSIS for an application performed in an edible-vegetable oils manufacturer firm operating in Turkey to develop an organizational strategy for distribution channel management.

Studies regarding course selection is available in the literature. Ersöz et al. (2011) developed a decision model about course selection in graduate education. They used ANP in weighting criteria and TOPSIS in ranking alternative courses. Their decision criteria include course content, course time, course instructor, the experience of the persons concerned, sufficiency of the course, and practical/theoretical structure of the course. They concluded that course content (0,291) and instructor (0,267) are the most important criteria while determinining elective course. Demir and Ok (1996) got the opinions of 91 faculty members and 189 students at METU on elective course system. In their study, Tezcan, and Gümüş investigated the factors affecting the choice of elective cource in undergraduate education. The sample of the study consisted of 300 undergraduate students. Data was gathered by using a questionnaire. They found that while in chemistry department the most important factor effecting the elective course decision is the opinions of the students about course instructor, in physics department the most effective factor on the determination of elective course is the closeness to the course that was previously received and the student was successful. In biology department, the most important factor was found as technique of the course. Dündar (2008), applied AHP in course selection. In the study, three criteria including characteristics of the course instructor, the name and content of the course, and the information about the course obtained from the other students were determined. The most important criteria in the study was found as characteristics of the course instructor (0,38). The information about the course obtained from the other students criteria followed it with an average of 0,34.

2. Hierarchical Fuzzy TOPSIS Method

TOPSIS (Technique for Order Preference by Similarity to Ideal Solution), one of the MCDM method proposed by Hwang ve Yoon (1981), has been widely used in the literature and bases on choosing the alternative that has the shortest distance from the positive ideal solution (PIS) and the farthest from the negative ideal solution (NIS) (Chen, 2000; 2).

Because of the fact that human considerations and judgments are often vague and human process of thought is not adaptable to be expressed in exact numerical values, a more realistic approach may be to use linguistic variables instead of numerical values. FTOPSIS, one of the FMCDM method, very suitable for solving the decision making problem under fuzzy environment. In this method, the importance weights of various criteria and the evaluations of the alternatives with respect to the criteria are expressed as linguistic variables (Chen, 2000; 4-5).

Table 1. Linguistic Variables for Importance Weight of Each Criterion

Very High (VH)	(0.8, 1.0, 1.0)
High (H)	(0.6, 0.8, 1.0)
Medium (M)	(0.3, 0.5, 0.7)
Law (L)	(0, 0.2, 0.4)
Very Law (VL)	(0, 0, 0.2)

Table 2. Linguistic Variables for the Evaluation of the Alternatives

Very Good (VG)	(8, 10, 10)
Good (G)	(6, 8, 10)
Fair (F)	(3, 5, 7)
Poor (P)	(0, 2, 4)
Very Poor (VP)	(0, 0, 2)

The linguistic variables for evaluation of importance weight of criterion and alternatives used in this study are given in Table 1 and Table 2 respectively.

HFTOPSIS method which includes $\tilde{I}_{MC}$, $\tilde{I}_{SC}$, and $\tilde{I}_{A}$ differs from FTOPSIS method with the presence of sub-criteria.

Suppose that we have *n* main criteria (MC), *m* sub-criteria (SC), *k* alternatives, and *s* decision makers. Each main criteria has r_i sub-criteria and *m* as the total number of sub-criteria is calculated as follows:

$$\sum_{i=1}^{m} r_i \tag{1}$$

$\tilde{I}_{MC}$, is constructed by the evaluation of the weights of the main criteria with respect to the goal and is shown as follows:

$$\tilde{I}_{MC} = \begin{array}{c} \\ MC_1 \\ MC_2 \\ \vdots \\ MC_p \\ \vdots \\ MC_n \end{array} \begin{array}{c} \text{Goal} \\ \begin{bmatrix} \tilde{w}_1 \\ \tilde{w}_2 \\ \vdots \\ \tilde{w}_p \\ \vdots \\ \tilde{w}_n \end{bmatrix} \end{array} \tag{2}$$

where; $\tilde{w}_p$, is the arithmetic mean of the weights determined by the decision makers and is calculated using:

$$\tilde{w}_p = \frac{\sum_{i=1}^{s} \tilde{w}_{pi}}{s}, \quad p = 1, 2, \ldots, n \tag{3}$$

In Equation (3), $\tilde{w}_{pi}$ expresses the fuzzy evaluation score of main criteria *p* with respect to goal assessed by the decision maker *i*.

$\tilde{I}_{SC}$, symbolizing the weights of the sub-criteria with respect to the main criteria is constructed as follows:

$$\tilde{I}_{SC} = \begin{array}{c|cccccc|}
 & \tilde{w}_1 & \tilde{w}_2 & \cdots & \tilde{w}_p & \cdots & \tilde{w}_n \\
 & MC_1 & MC_2 & \cdots & MC_p & \cdots & MC_n \\
\hline
SC_{11} & \tilde{w}_{11} & 0 & \cdots & 0 & \cdots & 0 \\
SC_{12} & \tilde{w}_{12} & 0 & \cdots & 0 & \cdots & 0 \\
\vdots & \vdots & \vdots & & \vdots & & \vdots \\
SC_{1r_1} & \tilde{w}_{1n} & 0 & \cdots & 0 & \cdots & 0 \\
SC_{21} & 0 & \tilde{w}_{21} & \cdots & 0 & \cdots & 0 \\
SC_{22} & 0 & \tilde{w}_{22} & \cdots & 0 & \cdots & 0 \\
\vdots & \vdots & \vdots & & \vdots & & \vdots \\
SC_{2r_2} & 0 & \tilde{w}_{2r_2} & \cdots & 0 & \cdots & 0 \\
\vdots & \vdots & 0 & & & & \vdots \\
SC_{p1} & 0 & 0 & \cdots & \tilde{w}_{p1} & \cdots & 0 \\
\vdots & \vdots & \vdots & & & & 0 \\
SC_{n1} & 0 & 0 & \cdots & 0 & \cdots & \tilde{w}_{n1} \\
SC_{n2} & 0 & 0 & \cdots & 0 & \cdots & \tilde{w}_{n2} \\
\vdots & \vdots & \vdots & & \vdots & & \vdots \\
SC_{nr_n} & 0 & 0 & \cdots & 0 & \cdots & \tilde{w}_{nr_n}
\end{array} \qquad (4)$$

where; $\tilde{w}_{pl}$, is the arithmetic mean of the weights determined by the decision makers and is calculated using:

$$\tilde{w}_{pl} = \frac{\sum_{i=1}^{s} \tilde{w}_{pli}}{s} \qquad (5)$$

In Equation (5), $\tilde{w}_{pli}$ expresses the weight of the sub-criteria *l* with respect to the main criteria *p* determined by decision maker *i*.

$\tilde{I}_A$ is constructed by the scores of the alternatives with respect to the sub-criteria and given as follows:

$$\tilde{I}_A = \begin{array}{c|ccccccccc|}
 & \tilde{W}_{11} & \tilde{W}_{12} & \cdots & \tilde{W}_{1r_1} & \cdots & \tilde{W}_{pl} & \cdots & \tilde{W}_{nr_n} \\
 & SC_{11} & SC_{12} & \cdots & SC_{1r_1} & \cdots & SC_{pl} & \cdots & SC_{nr_n} \\
\hline
A_1 & \bar{c}_{111} & \bar{c}_{112} & \cdots & \bar{c}_{11r_1} & \cdots & \bar{c}_{1pl} & \cdots & \bar{c}_{1nr_n} \\
A_2 & \bar{c}_{211} & \bar{c}_{212} & \cdots & \bar{c}_{21r_1} & \cdots & \bar{c}_{2pl} & \cdots & \bar{c}_{2nr_n} \\
\vdots & \vdots & \vdots & & \vdots & & \vdots & & \vdots \\
A_q & \bar{c}_{q11} & \bar{c}_{q12} & \cdots & \bar{c}_{q1r_1} & \cdots & \bar{c}_{qpl} & \cdots & \bar{c}_{qnr_n} \\
\vdots & & \vdots & & \vdots & & \vdots & & \vdots \\
A_k & \bar{c}_{k11} & \bar{c}_{k12} & \cdots & \bar{c}_{k1r_1} & \cdots & \bar{c}_{kpl} & \cdots & \bar{c}_{knr_n}
\end{array} \qquad (6)$$

where;

$$\tilde{W}_{pl} = \tilde{w}_p \tilde{w}_{pl} \qquad (7)$$

$\tilde{c}_{qpl}$ in $\tilde{I}_A$ matrix is the arithmetic means of the scores determined by the decision makers and is calculated as follows:

$$\tilde{c}_{qpl} = \frac{\sum_{i=1}^{s} \tilde{c}_{qpli}}{s} \tag{8}$$

where; $\tilde{c}_{qpli}$ expresses the fuzzy evaluation score of alternative *q* with respect to sub-criteria *l* under main criteria *p* assessed by decision maker *i*.

The steps of the HFTOPSIS algorithm are explained below.

Step 1: Fuzzy decision matrix ($D = \left[\tilde{x}_{ij}\right]$), $\tilde{x}_{ij} = \left(a_{ij}, b_{ij}, c_{ij}\right)$, is constructed as a result of the linguistic evaluation of the alternatives with respect to the sub-criteria as in Equation (6).

Step 2: Normalized fuzzy decision matrix ($D' = \left[\tilde{r}_{ij}\right]$) is constructed. The transformation from fuzzy decision matrix to normalized fuzzy decision matrix is done by using linear scale transformation given in Equations (9) and (10).

$$\tilde{r}_{ij} = \left(\frac{a_{ij}}{c_j^*}, \frac{b_{ij}}{b_j^*}, \frac{c_{ij}}{a_j^*}\right), \quad j \in B, \quad a_j^* = \max a_{ij}\ ,\ b_j^* = \max b_{ij}\ \text{ ve } c_j^* = \max c_{ij} \tag{9}$$

$$\tilde{r}_{ij} = \left(\frac{a_j^-}{c_{ij}}, \frac{b_j^-}{b_{ij}}, \frac{c_j^-}{a_{ij}}\right), \quad j \in C, \quad a_j^- = \min a_{ij}\ ,\ b_j^- = \min b_{ij}\ \text{ ve } c_j^- = \min c_{ij} \tag{10}$$

In Equations (9) and (10), B indicates benefit criteria and C indicates cost criteria.

Step 3: Weighted normalized fuzzy decision matrix $V = \left[\tilde{v}_{ij}\right]$ is set as follows:

$$\tilde{v}_{ij} = \tilde{r}_{ij} \times \tilde{w}_j^* \tag{11}$$

Step 4: Positive ideal solution and negative ideal solutions are obtained. Positive ideal solution (A^*) is the solution that maximizes benefit criteria and at the same time minimizes cost criteria when in contrast negative ideal solution (A^-) maximizes cost criteria and minimizes benefit criteria (Wang and Elhag, 2006; 310).

$$A^* = \left[\tilde{v}_1^*, \tilde{v}_2^*, \ldots\ldots\ldots, \tilde{v}_n^*\right], \quad \tilde{v}_j^* = \max \tilde{v}_{ij} \tag{12}$$

$$A^- = \left[\tilde{v}_1^-, \tilde{v}_2^-, \ldots\ldots\ldots, \tilde{v}_n^-\right], \quad \tilde{v}_j^- = \min \tilde{v}_{ij} \tag{13}$$

Step 5: Generalized means ($M\left(\tilde{v}_{ij}\right)$) for $\tilde{v}_{ij}$ are computed. $\tilde{v}_j^*$, and $\tilde{v}_j^-$ values are the fuzzy numbers with the largest generalized mean and the smallest generalized mean respectively. The generalized mean for $\tilde{v}_{ij}$ is defined as:

$$M\left(\tilde{v}_{ij}\right) = \frac{-a_{ij}^2 + c_{ij}^2 - a_{ij} b_{ij} + b_{ij} c_{ij}}{\left[3\left(-a_{ij} + c_{ij}\right)\right]} \tag{14}$$

For each column j, we find $\tilde{v}_{ij}$ whose greatest mean is $\tilde{v}_j^*$ and lowest mean is $\tilde{v}_j^-$ (Kahraman et al., 2007a; 152).

Step 6: Distances from positive ideal solution (S_i^*) and negative ideal solution (S_i^-) are determined using:

$$S_i^* = \sum_{i=1}^{n} D_{ij}^*, \quad i = 1, 2, \ldots\ldots\ldots, m \tag{15}$$

$$S_i^- = \sum_{i=1}^{n} D_{ij}^-, \quad i = 1, 2, \ldots\ldots\ldots, m \tag{16}$$

In Equations (15) and (16), D_{ij}^* ve D_{ij}^- values that are crisp numbers are calculated as follows (Kahraman et al., 2007a):

$$D_{ij}^* = \begin{cases} 1 - \dfrac{c_{ij} - a^*}{b^* + c_{ij} - a^* - b_{ij}}, & b_{ij} < b^* \\ 1 - \dfrac{c^* - a_{ij}}{b_{ij} + c^* - a_{ij} - b^*}, & b_{ij} > b^* \end{cases}, \quad \forall_{i,j} \tag{17}$$

$$D_{ij}^- = \begin{cases} 1 - \dfrac{c^- - a_{ij}}{b_{ij} + c^- - a_{ij} - b^-}, & b^- < b_{ij} \\ 1 - \dfrac{c_{ij} - a^-}{b^- + c_{ij} - a^- - b_{ij}}, & b^- > b_{ij} \end{cases}, \quad \forall_{i,j} \tag{18}$$

In this study, to calculate D_{ij}^* ve D_{ij}^- values, Equation (17) and Equation (18) used in Kahraman et al. (2007a) and Vertex method used in Chen (2000) are applied. Then the results of the two approaches are compared.

Vertex Method is defined as the Euclidean distance of two triangular fuzzy numbers $\tilde{a} = (a_1, a_2, a_3)$ and $\tilde{b} = (b_1, b_2, b_3)$ as follows:

$$d(\tilde{a}, \tilde{b}) = \sqrt{\frac{1}{3}\left[(a_1 - b_1)^2 + (a_2 - b_2)^2 + (a_3 - b_3)^2\right]} \tag{19}$$

Step 7: Closeness coefficients of the alternatives are calculated by using:

$$C_i = \frac{S_i^-}{S_i^- + S_i^*} \tag{20}$$

The alternatives are ranked by determining closeness coefficient, the value of which is between 0 and 1.

Table 3. Assessment Status of the Chosen Alternative in Accordance with Its Closeness Coefficient

Closeness Coefficient (C_i)	**Assessment Status**
$C_i \in [0, 0.2)$	Do not recommend.
$C_i \in [0.2, 0.4)$	Recommend with high risk.
$C_i \in [0.4, 0.6)$	Recommend with low risk.
$C_i \in [0.6, 0.8)$	Approved.
$C_i \in [0.8, 1.0)$	Approved and preferred.

Source: Chen et al., 2006; 296.

Although we can determine the ranking order of all feasible alternatives, a more realistic approach may be to use a linguistic variable to describe the current assessment status of each alternative in accordance with its closeness coefficient. Assessment status of the chosen alternative in accordance with its closeness coefficientis are given in Table 3 (Chen et al., 2006; 295-296).

3. Results

In this study, a decision model based on the process of determining elective course belonging to the sixth semester of third year students receiving education in economics department at a state university is developed. We have 6 main criteria, 17 sub-criteria and 3 alternatives in the study. Hierarchical structure among the goal, main criteria and sub-criteria in this study is illustrated in Figure 1.

In the first hierarchical level there is the goal, in other words, "determining the most appropriate elective course".

In the second hierarchical level there are six main criteria. These are as follows: MC_1: Course content, MC_2: Teaching method and learning environment of the course, MC_3: Course materials, MC_4: Elements relating to the lecturer, MC_5: Assessment system, MC_6: Elements relating to decision maker.

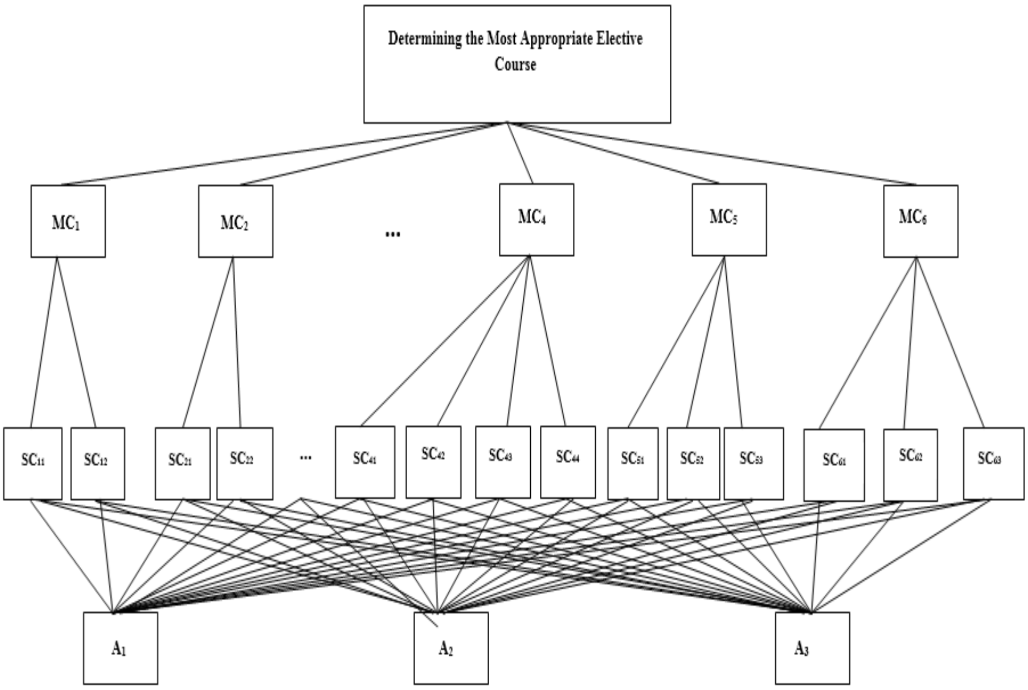


Figure 1. Hierarchical Structure of the Elective Course Selection

In the third hierarchical level there are seventeen sub-criteria. These are as follows:

- Sub-criteria under course content main criteria are: SC_{11}: Suitability of the course content to the purpose and scope of the course, SC_{12}: Contribution of the theoretical content and applications (projects, assignments etc.) of the course to the future professional career;
- Sub-criteria under teaching method and learning environment of the course main criteria are: SC_{21}: Holding interactive courses, SC_{22}: Having sufficient projects and assignments consolidating theoretical knowledge;
- Sub-criteria under course materials main criteria are: SC_{31}: Having a main source used in the course, SC_{32}: Suitability of the sources used in the course to the course content, SC_{33}: Up-to-date sources used in the course;
- Sub-criteria under elements relating to the lecturer main criteria are: SC_{41}: Lecturer's valuing students, SC_{42}: Lecturer's good communication with the students, SC_{43}: Lecturer's proficiency in the course, $SC_{44:}$ Lecturer's desire and enthusiasm to his profession;
- Sub-criteria under assessment system main criteria are: SC_{51}: Flexibility of the assessment system, SC_{52}: Type of the assessment system $SC_{53:}$ Giving importance to participation in the assessment system;
- Sub-criteria under elements relating to decision maker main criteria are: SC_{61}: The level of familiarity to the course topics, SC_{62}: The level of interest in the course topics, SC_{63}: The belief that success will be achieved.

In the fourth hierarchical level there are three alternatives as elective courses opened in the sixth semester and are assessed by the decision makers in this context.

Five decision makers assess the importance of main criteria for the goal and the importance of each sub-criteria for the main criteria by linguistic variables given in Table 1. Then, the linguistic evaluations are transformed into corresponding triangular fuzzy numbers by using Table 1. Fuzzy weights of main criteria are calculated by using Equation (3) and after the calculation of fuzzy weights of all main criteria, $\tilde{I}_{MC}$ matrix is constructed. And for the construction of $\tilde{I}_{SC}$ matrix, fuzzy weights of sub-criteria are calculated by using Equation (5). $\tilde{I}_{MC}$ and $\tilde{I}_{SC}$ matrices are given in Table 4 and Table 5 respectively.

Table 4. $\tilde{I}_{MC}$ Matrix

MC_1	(0.68, 0.88, 1.00)
MC_2	(0.58, 0.78, 0.94)
MC_3	(0.30, 0.50, 0.70)
MC_4	(0.76, 0.96, 1.00)
MC_5	(0.62, 0.82, 0.94)
MC_6	(0.62, 0.82, 0.94)

All decision makers evaluate the alternatives with respect to sub-criteria with linguistic variables given in Table 2. Then linguistic variables are transformed into corresponding triangular fuzzy numbers by using Table 2. And the scores of the each alternative for each sub-criteria are calculated by Equation (8) and $\tilde{I}_{A}$ matrix is constructed as shown in Table 6.

In the next step, normalized fuzzy decision matrix, and weighted normalized decision matrix are obtained. In the study, because all criteria are assessed as benefit criteria, Equation (9) and Equation (11) are applied to find $\tilde{r}_{ij}$ and $\tilde{v}_{ij}$ values respectively.

Table 5. $\tilde{\mathbf{I}}_{\mathbf{SC}}$ Matrix

	MC_1	**MC_2**	**MC_3**	**MC_4**	**MC_5**	**MC_6**
SC_{11}	(0.58, 0.78, 0.94)	0	0	0	0	0
SC_{12}	(0.62, 0.82, 0.94)	0	0	0	0	0
SC_{21}	0	(0.52, 0.72, 0.88)	0	0	0	0
SC_{22}	0	(0.30, 0.50, 0.70)	0	0	0	0
SC_{31}	0	0	(0.28, 0.44, 0.60)	0	0	0
SC_{32}	0	0	(0.34, 0.54, 0.70)	0	0	0
SC_{33}	0	0	(0.36, 0.56, 0.76)	0	0	0
SC_{41}	0	0	0	(0.60, 0.80, 0.88)	0	0
SC_{42}	0	0	0	(0.66, 0.86, 0.94)	0	0
SC_{43}	0	0	0	(0.70, 0.90, 0.94)	0	0
SC_{44}	0	0	0	(0.66, 0.86, 0.94)	0	0
SC_{51}	0	0	0	0	(0.52, 0.72, 0.88)	0
SC_{52}	0	0	0	0	(0.72, 0.92, 1.00)	0
SC_{53}	0	0	0	0	(0.62, 0.82, 0.94)	0
SC_{61}	0	0	0	0	0	(0.36, 0.56, 0.76)
SC_{62}	0	0	0	0	0	(0.52, 0.72, 0.88)
SC_{63}	0	0	0	0	0	(0.58, 0.78, 0.94)

Table 6. $\tilde{\mathbf{I}}_{\mathbf{A}}$ Matrix

	SC_{11}	**SC_{12}**	**SC_{21}**	**SC_{22}**	**SC_{31}**	**SC_{32}**
A_1	(6.40, 8.40, 10.00)	(5.60, 7.60, 8.80)	(5.20, 7.20, 8.80)	(3.60, 5.60, 7.60)	(6.40, 8.40, 10.00)	(5.80, 7.80, 9.40)
A_2	(6.20, 8.20, 9.40)	(5.20, 7.20, 8.80)	(4.60, 6.60, 8.20)	(1.80, 3.40, 5.40)	(5.20, 7.20, 8.80)	(6.20, 8.20, 9.40)
A_3	(6.20, 8.20, 9.40)	(6.00, 8.00, 8.80)	(7.20, 9.20, 10.00)	(5.60, 7.60, 8.80)	(4.20, 5.80, 7.80)	(5.80, 7.80, 9.40)
	SC_{33}	**SC_{41}**	**SC_{42}**	**SC_{43}**	**SC_{44}**	**SC_{51}**
A_1	(7.20, 9.20, 10.00)	(7.60, 9.60, 10.00)	(7.20, 9.20, 10.00)	(7.20, 9.20, 10.00)	(8.00, 10.00, 10.00)	(4.80, 6.80, 8.80)
A_2	(5.20, 7.20, 8.80)	(5.60, 7.60, 8.80)	(5.00, 7.00, 8.20)	(5.80, 7.80, 9.40)	(5.60, 7.60, 8.80)	(3.00, 4.60, 6.60)
A_3	(5.60, 7.60, 8.80)	(6.60, 8.60, 9.40)	(6.60, 8.60, 9.40)	(6.80, 8.80, 10.00)	(7.00, 9.00, 9.40)	(5.80, 7.80, 9.40)
	SC_{52}	**SC_{53}**	**SC_{61}**	**SC_{62}**	**SC_{63}**	
A_1	(6.20, 8.20, 9.40)	(5.80, 7.80, 9.40)	(5.20, 7.20, 8.80)	(5.80, 7.80, 9.40)	(7.20, 9.20, 10.00)	
A_2	(3.60, 5.60, 7.60)	(4.20, 6.20, 8.20)	(4.20, 6.20, 8.20)	(4.20, 6.20, 8.20)	(4.60, 6.20, 7.80)	
A_3	(5.40, 7.40, 9.40)	(6.80, 8.80, 10.00)	(5.80, 7.80, 9.40)	(5.20, 7.20, 8.80)	(4.60, 6.60, 8.20)	

After obtaining weighted normalized decision matrix, positive and negative ideal solutions are determined. To find positive and negative ideal solution values, generalized means are calculated by using Equation (14).

For the next step of the algorithm, distances from positive and negative ideal solutions for each alternative are computed by using Equation (15) and (16) respectively. To find distance from positive and negative ideal solutions, Equation (17) and Equation (18) are applied for the first approach and also we performed Vertex method given in Equation (19) as a second approach.

In the next step, we find closeness coefficients of each candidate elective course by using Equation (20) and the candidate elective courses are ranked from the best to the worst with respect to the calculated closeness coefficients. For the last step, assessment status of the chosen alternative in accordance with its closeness coefficient is performed.

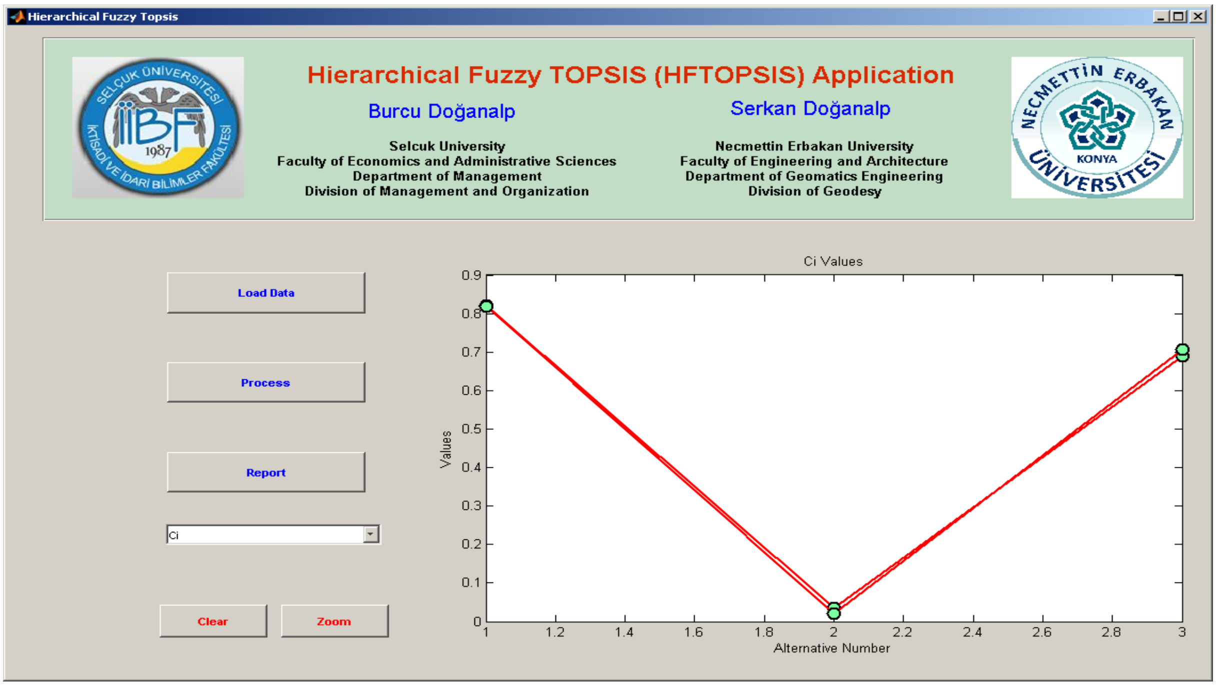
The ranking order of three alternative elective courses is similar according to the two approaches handled in the study: $A_1 > A_3 > A_2$. It is seen that the most appropriate elective course is A_1 with a closeness coefficient 0.821 according to the first approach and 0.819 according to the second approach.

Table 7. S_i^* S_i^* , S_i^- , C_i Values

Alternatives (A)	First Approach			Second Approach		
	S_i^*	S_i^-	C_i	S_i^*	S_i^-	C_i
A_1	0.477	2.190	0.821	0.430	1.953	0.819
A_2	2.584	0.092	0.034	2.327	0.052	0.022
A_3	0.838	1.861	0.689	0.709	1.698	0.706

When the evaluation about whether the choice is risky or not via the closeness coefficient of A_1 is made, it can be expressed that the alternative chosen is approved and preferred.

MATLAB R2010b software is used to evaluate the results of alternative elective courses. After the construction of $\tilde{I}_{MC}$, $\tilde{I}_{SC}$ ve $\tilde{I}_{A}$, triangular fuzzy numbers in the matrices are entered to the pages created for each in Microsoft Excel programme. With the help of the codes, algorithm of HFTOPSIS method in MATLAB R2010b software is established. It becomes possible to load the data from Excel, to evaluate these data with algorithm, display results as report file and provide distances of alternatives from positive and negative ideal solutions, closeness coefficients and normalized closeness coefficients of them graphically in the context of two approaches used in the study. This process can be seen via Figure 2.



Hierarchical Fuzzy TOPSIS (HFTOPSIS) Application

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Figure 2. An Image from the Developed Programme

4. Discussion and Conclusion

Elective course selection is a complex problem which many qualitative criteria must be considered. These kinds of criteria make the evaluation process hard and vague. Hierarchical structure is a good approach to describe complicated system. Moreover the judgments from decision makers are always in vague rather than in crisp numbers. It is suitable and flexible to express the judgments of decision makers in fuzzy number instead of in crisp number.

This study presents a FMCDM model relating to the elective course selection in undergraduate education. In this study, the process of determinig elective course is handled with HFTOPSIS method. The aim of this study is introducing a programme developed in MATLAB software related to FMCDM model based on HFTOPSIS being used while decision making under the fuzzy environment. For the application, as decision makers, five third year economics department students at a state university evaluate main and sub-criteria and the candidate elective courses opened in the department of economics for the sixth semester by using linguistic variables. Then, these linguistic data are transformed into triangular fuzzy numbers, used in two different algorithms of HFTOPSIS and, relevant process is programmed, and the results of the two algorithms are compared.

In the study it is concluded that the most important decision criteria for determining the elective course is elements relating to the lecturer (0.76, 0.96, 1.00). Course content follows it with an importance weight 0.68, 0.88, 1.00. Decision makers express that the criteria having the least effect on this decision is course materials (0.30, 0.50, 7.00).

The data obtained from the evaluation of three elective courses by decision makers is used in the algorithm of HFTOPSIS method. Alternative elective courses are ranked from the best to the worst with respect to the calculated closeness coefficients. According to the closeness coefficient of three alternatives, the ranking order of three alternative elective courses is determined as $A_1 > A_3 > A_2$. It is seen that the ranking order of three alternative elective courses doesn't change when the results of two approaches handled in the study are compared.

When the evaluation about whether the choice is risky or not via the closeness coefficient of A_1, and Table 3 (0.821 according to the first approach and 0.819 according to the second approach) is made, it can be expressed that the alternative chosen is approved and preferred.

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