International Journal of Engineering and Applied Sciences (IJEAS)
ISSN: 2394-3661, Volume-5, Issue-5, May 2018

Weapon Selection Problem With AHP And Topsis Methods In Multi Criteria Decision Making

Muhammed Furkan Karaburun, Kemal Alaykiran

Abstract— **It is obvious that the people in the security sector are at more risk than other individuals in different job disciplines in society due to their working conditions. For this reason, it is expected that individuals working in the security sector to choose a weapon to be suitable for the field of use as a decision maker. In recent years, Multiple Criteria Decision Making (MCDM) has been a field of interest where researchers have been increasingly studying on due to its simplicity, ease to understand, and also ease of implementation. MCDM methods also help the decision maker to choose the best alternative by evaluating conflicting criteria.**

In this study, a solution proposal is presented to decision makers using AHP (Analytic Hierarchy Process) and TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method.

First of all, criteria and alternatives are obtained using the fishbone diagram at the end of the wide participation brainstorming meetings with individuals working in the security sector. The criteria weight values are calculated by the AHP method, then alternatives are ranked by using the TOPSIS method.

It is considered that the findings obtained through the study will contribute to the decision makers to be more careful in selecting weapons, especially against the hazards arising from machine and human errors. In addition, the findings obtained from this study are considered to contribute positively to management and production processes in order to obtain better quality products by the companies operating in the arms sector .

Index Terms— **AHP Method, Multi Criteria Decision Making, TOPSIS Method, Weapon Selection.**

I. INTRODUCTION

It is obvious that the people in the security sector are at more risk than other individuals in different businesses in society due to their working conditions. Therefore, it is very important that the individuals working in the security sector to make the best choice of arms to be compatible with the field of use as a decision maker.

In this study, it is aimed to look at the decision making processes of individuals working in security sector using AHP (Analytic Hierarchy Process) and TOPSIS (Technique for Order Preference by Similarity to Ideal Solution), which are frequently used in literature, from MCDM techniques that allow to find the option that most effectively performs the conflicting objectives by taking into consideration multiple criteria.

The findings from the study are particularly important for decision makers to be more attentive and sensitive to the dangers caused by the selection of the wrong weapon, as well as to contribute to the more accurate decisions in the arms trading process.

Moreover, the findings obtained this study are evaluated and it is thought that it can contribute positively to the competitiveness of the market by increasing the effectiveness and productivity of production process, based on the importance values given to the main criteria, in order to ensure that the companies operating in the arms industry are able to produce better quality products.

II. METHODOLOGY

A. Analytic Hierarchy Process Method

The AHP method is a widely used, easy-to-understand and reliable method that allows decision makers to synthesize qualitative and quantitative factors in decision making process [1].

AHP was proposed by Saaty[2]. The main objective of the method is to model a decision making process with subjective issues and based on multiple attributes in a hierarchical system [2].

It is one of the most frequently used techniques for solving complex problem, which are developed to allow the decision alternatives and criteria to be sorted on a numerical scale and which include multiple evaluation factors.

1) Creating Structure of the Hierarchy

The goal to be achieved at the highest level, the criteria to be used in order to achieve this target in the middle level and a structure in which alternatives are found at the lowest level are obtained.

2) Preparation of Pairwise Comparison Matrix

After establishing a hierarchical model in the AHP Method, a pairwise comparison matrix must be created to determine the relative importance of all elements on each other. When creating this matrix the decision-maker sets the importance levels for each pairwise comparison matrix.

If there is no numerical scale then the verbal value judgments for pairwise comparison matrix should be translated into numerical values through by a scale that determines both the direction and the severity of these preferences.

For this reason, to determine the superiority the scale of importance given in Table I, which was developed by Saaty is frequently used in the literature [3].

Muhammed Furkan Karaburun, Department of Industrial Engineering, University of Necmettin Erbakan, Konya, Turkey

Kemal Alaykıran, Department of Industrial Engineering, University of Necmettin Erbakan, Konya, Turkey

TABLE I. 1-9 Importance Scale

Importance Level	Definition	Description
1	Equal importance	i is equally important
3	Moderate importance	i is moderately important to j
5	Strong importance	i is strongly important to j
7	Very strong importance	i is very strongly important to j
9	Extremly importance	i is very absolutely important to j
2, 4, 6, 8	Intermediate values	The relative importance of i to j is between to adjacent judgment

The verbal data to be obtained from the personal value judgments of the decision-makers are converted into numerical values through the comparative table given in Table 1 to obtain the binary comparison matrix given in general in Equation 1 [4].

$$A_{ij} = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1j} \\ a_{21} & a_{22} & \cdots & a_{2j} \\ \vdots & \vdots & \vdots & \vdots \\ a_{i1} & a_{i2} & \cdots & a_{ij} \end{bmatrix} \quad (1)$$

The main attribute of the AHP method is the determination of the relative importance weights of the decision alternatives through the comparison chart given in Table I. In case of a problem with solved using the AHP method, we assumed that we are interested in n quantifiable criteria; we are creating n x n dimensional pairwise comparison matrix that reflects the relative importance of the different of the decision-maker and is defined as A.

The pairwise comparison operation is performed by grading the criteria in line i row $(i = 1, 2, \ldots, n)$ according to each criterion represented by the n column. a_{ij} matrix values are defined as the element of A (i,j) and are created by means of the importance scale given in Table I. To obtain a consistent matrix structure $a_{ij} = k$, $a_{ji} = 1/k$ should be expressed. Furthermore, all the diagonal a_{ij} elements of A must take the value 1 because they rate the criterion depending on them [5].

In the AHP Model established in order to achieve a specific goal, if there is a multiple decision-making group unlike a single decision-making group, the decision-makers will either convene to make a joint decision or will be transformed into a single pairwise comparison matrix by using the geometric mean method of each decision-making unit and then the AHP method will be implemented [6].

The geometric mean approach used for this purpose, the common decision of n decision makes is reduced to a single pairwise comparison matrix by using the formula given in Equation 2 using the geometric mean method. Here a_{ij}^k represents comparison value of **i-th** criteria/factor [4].

$$a_{ij}^k = \left[a_{ij}^1 * a_{ij}^2 * \ldots * a_{ij}^n\right]^{\frac{1}{n}} \quad (2)$$

3) Calculation of the Normalized Pairwise Comparison Matrix

The first values in the A_{ij} initial matrix are expressed as 0 to 1 numerical values using the formulas in Equation 3, based on the numerical or verbal value judgments of the decision makers.

$$b_{ij} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}} \quad (3)$$

Where, the normalized pairwise comparison N_{ij} matrix calculated using the formula given in Equation 3 is shown as standard in Equation 4.

$$N_{ij} = \begin{bmatrix} b_{11} & b_{12} & \cdots & b_{1j} \\ b_{21} & b_{22} & \cdots & b_{2j} \\ \vdots & \vdots & \vdots & \vdots \\ b_{i1} & b_{i2} & \cdots & b_{ij} \end{bmatrix} \quad (4)$$

4) Calculation of the Weight Matrix

The values of b_{ij} in the normalized pairwise comparison matrix are obtained by taking the average of each row through the formulas given in Equation 5.

$$W_i = \frac{\sum_{j=1}^{n} b_{ij}}{n} \quad (5)$$

This matrix which is obtained for each row, constitutes the W_i weight matrix given in Equation 6. Where, the column values of the W_i matrix represent the significance distributions of the relevant variables.

$$W_i = \begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{bmatrix} \quad (6)$$

5) Execution of Consistency Test Procedures

In the AHP method, decision makers are expected to behave consistent when creating pairwise comparison matrix. Mathematically, if the expression given in Equation 7 is true for all i, j **and** k, then the A pairwise comparison matrix is consistent.

$$a_{ij} \cdot a_{jk} = a_{ik} \quad (7)$$

This property given in Equation 7 requires that all the columns of A (hence rows) of a be linearly dependent. This mean that any **2x2** dimensional pairwise comparison matrix will always be consistent [5].

The matrix N will be obtained as given in Equation 8, where all the columns (hence rows) are equal from the pairwise binary comparison matrix that we will regard as perfectly consistent.

$$N = \begin{bmatrix} w_1 & w_1 & \cdots & w_1 \\ w_2 & w_2 & \cdots & w_2 \\ \vdots & \vdots & \vdots & \vdots \\ w_n & w_n & \cdots & w_n \end{bmatrix} \quad (8)$$

Then we divide the **i-th** column elements of N by w_i to produce a matrix of equivalence A (the inverse of A to N matrix formation). Thus, the matrix given in Equation 9 will be obtained.

$$A = \begin{bmatrix} 1 & \frac{w_1}{w_2} & \cdots & \frac{w_1}{w_n} \\ \frac{w_2}{w_1} & 1 & \cdots & \frac{w_2}{w_n} \\ \vdots & \vdots & \vdots & \vdots \\ \frac{w_n}{w_1} & \frac{w_n}{w_2} & \cdots & 1 \end{bmatrix} \quad (9)$$

Therefore, the matrix in Equation 10 will be obtained by starting from the definition of $\mathbf{A}$.

$$\begin{bmatrix} 1 & W_1/W_2 & W_1/W_3 & \cdots & W_1/W_n \\ W_2/W_1 & 1 & W_2/W_3 & \cdots & W_2/W_n \\ W_3/W_1 & W_3/W_2 & 1 & \cdots & W_3/W_n \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ W_n/W_1 & W_n/W_2 & W_n/W_3 & \cdots & 1 \end{bmatrix} \cdot \begin{bmatrix} W_1 \\ W_2 \\ W_3 \\ \vdots \\ W_n \end{bmatrix} = \begin{bmatrix} n.W_1 \\ n.W_2 \\ n.W_3 \\ \vdots \\ n.W_n \end{bmatrix} = n.\begin{bmatrix} W_1 \\ W_2 \\ W_3 \\ \vdots \\ W_n \end{bmatrix} \quad (10)$$

Thus, to summarize, $\mathbf{A}$ is consistent if and only if a general mathematical equality of Equation 11 is provided.

$$A.w = n.W \quad (11)$$

Where $\mathbf{w}$ is the column vector of the relative weights of $\mathbf{w_i}$ $(\mathbf{i = 1, 2, \ldots, n})$.

Value of the $\mathbf{n_{max}}$ is the sum of the columns of the matrix obtained by multiplying the $\mathbf{W_i}$ weight matrix given in Equation 6 with the $\mathbf{A_{ij}}$ matrix given in Equation 1 by according to Equation 11 [5].

In contrast to all controls, if the columns of the pairwise comparison matrix in Equation 4 are not identical the AHP method calculates the $\mathbf{CR}$ (Consistency Ratio) value by using the formula given in Equation 12.

$$CR = \frac{CI}{RI} \quad (12)$$

Here, $\mathbf{CI}$ (Consistency Index) value with the formula given in Equation 13,

$$CI = \frac{n_{max} - n}{n-1} \quad (13)$$

and then $\mathbf{RI}$ (Random Index) value is calculated using the formula given in Equation 14 [5].

$$RI = \frac{1,98 \cdot (n-2)}{n} \quad (14)$$

In addition, the frequently used random index table in the literature, which is constituted to include fixed values based on the number of criteria $(\mathbf{n})$ used in the pairwise comparison with respect to the calculation of the $\mathbf{CR}$ value, is given in Table II [7].

TABLE II. Random Index Table

n	3	4	5	6	7	8	9	10
RI	0,58	0,90	1,12	1,24	1,32	1,41	1,45	1,49

$\mathbf{CR}$ value obtained as a result of AHP method operations; If $\mathbf{CR \le 0,1}$, it is decided that the consistency level of the pairwise comparison matrix $(\mathbf{A})$ generated from the value judgments of the decision maker is at an acceptable level. Otherwise it is decided that the consistency level of the pairwise comparison matrix $(\mathbf{A})$ is not at an acceptable level. In this case, the decision maker should reconsider the value judgments and recreate the pairwise comparison matrix $(\mathbf{A})$, and then the AHP method operations must be recalculated.

6) Obtaining the General Result

The previous steps are calculated for all levels of the AHP method hierarchical model. Next, $\mathbf{mx1}$ dimensional (relative superiority column) vectors are determined which are generated according to the significance values of all n criteria given to the alternatives. Then these matrices are combined to obtain the pairwise comparison $\mathbf{DW}$ matrix of size $\mathbf{mxn}$.

We obtain the resultant vector $\mathbf{mx1}$ dimension $\mathbf{R}$ given in Equation 15 with $\mathbf{i = 1, 2, \ldots, m}$ and $\mathbf{j = 1, 2, \ldots, n}$ as the outcome of the matrix obtained above and the matrix $\mathbf{W_i}$ (relative superiority vector) of dimension $\mathbf{nx1}$. Then, the values of $\mathbf{R}$ vector (integrated weight) are ranked and the alternative with the greatest importance value is selected [4].

$$R = DW * W \quad (15)$$

B. Technique for Order Preference Similarity to Ideal Solution Method

It is not always possible to reach the ideal solution because of conflict between the criteria in multi-criteria decision making problems, and in this case a compromise solution is mentioned for solving the problem.

TOPSIS method was proposed by Hwang and Yoon to determine the best alternative based on the concepts of the compromise solution. The compromise solution is attempted to select the solution the shortest euclidean distance from the ideal solution and the farthest euclidean distance from the negative ideal solution [8].

1) Creating the Decision Matrix (A)

The decision matrix contains the decision variables to be ranked in the rows and the evaluation factors to be used in decision making in the columns.

The matrix $\mathbf{A_{ij}}$created by the decision maker is the initial matrix and is shown in Equation 16 as given in general representation.

$$A_{ij} = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ a_{m1} & a_{m2} & \cdots & a_{mn} \end{bmatrix} \quad (16)$$

In the initial decision matrix $\mathbf{A_{ij}}$, $\mathbf{m}$ in the rows denotes the number of the decision points, that is the alternatives; and $\mathbf{n}$ in the columns denotes the number of evaluation factors, that is, criteria.

2) Creating the Standard Decision Matrix (R)

The standard decision matrix $\mathbf{R_{ij}}$ given in Equation 18 is calculated using the elements of the initial matrix $\mathbf{A_{ij}}$ and using the formula in Equation 17. In fact, the process here is the process of standardizing the values in the $(\mathbf{A})$ decision matrix.

$$r_{ij} = \frac{a_{ij}}{\sqrt{\sum_{k=1}^{m} a_{kj}^2}} \quad (17)$$

$$R_{ij} = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{bmatrix} \quad (18)$$

3) Creating the Weighted Standard Decision Matrix (V)

First, it should be careful that the sum of $\mathbf{w_i}$ weight values obtained by AHP method for each evaluation factor of the decision maker is 1. Then, the elements in each column of the $\mathbf{R_{ij}}$ matrix are multiplied by the corresponding $\mathbf{w_i}$ values to obtain the $\mathbf{V_{ij}}$ decision matrix given in Equation 19.

$$V_{ij} = w_i * R_{ij} = \begin{bmatrix} w_1 r_{11} & w_2 r_{12} & \cdots & w_n r_{1n} \\ w_1 r_{21} & w_2 r_{22} & \cdots & w_n r_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ w_1 r_{m1} & w_2 r_{m2} & \cdots & w_n r_{mn} \end{bmatrix} \quad (19)$$

4) Finding of Ideal A^* and Negative Ideal A^- Solution Set

The TOPSIS method assumes that each evaluation factor has a monotone increasing or decreasing trend [9].

When constructing the ideal solution set in Equation 21, it is necessary to pay attention to which evaluation factor in the matrix V_{ij} is related whether the criterion is benefit-based or loss-based. If the relevant evaluation factor is based on benefit (max), the greatest value element of that column, if the relevant evaluation factor is based on loss (min), the smallest value element of that column is chosen to be selected by the formula given in Equation 20.

$$A^* = \{(\max_i V_{ij} \mid j \in J), (\min_i V_{ij} \mid j \in J')\} \quad (20)$$

$$A^* = \{v_1^*, v_2^*, \dots, v_n^*\} \quad (21)$$

When constructing the negative ideal solution set in Equation 23, it is necessary to pay attention to which evaluation factor in the matrix V_{ij} is related whether the criterion is benefit-based or loss-based. If the relevant evaluation factor is based on benefit (max), the smallest value element of that column, if the relevant evaluation factor is based on loss (min), the greatest value element of that column is chosen to be selected by the formula given in Equation 22.

$$A^- = \{(min_i V_{ij} \mid j \in J), (max_i V_{ij} \mid j \in J')\} \quad (22)$$

$$A^- = \{v_1^-, v_2^-, \dots, v_n^-\} \quad (23)$$

In the formulas given above; if the evaluation factors are benefit-based, J maximization in the ideal solution set and J minimization in the negative ideal solution set denotes. Likewise, if the evaluation factor is loss-based, J' minimization in the ideal solution set and J' maximization in the negative ideal solution set denotes. In addition, both the ideal and negative ideal solution set consists of elements as many as the number of evaluation factors (n) [4].

5) Calculation of Discrimination Measures

In the TOPSIS method, the euclidean distance approach is chosen to calculate the deviations of the evaluation factor values [8].

The deviation values for the decision points obtained in this way are called the ideal separation S_1^* and the negative ideal separation S_1^- measures and are calculated using the equations in Equation 24 and Equation 25.

$$S_i^* = \sqrt{\sum_{j=1}^{n} (V_{ij} - V_j^*)^2} \quad (24)$$

$$S_i^- = \sqrt{\sum_{j=1}^{n} (V_{ij} - V_j^-)^2} \quad (25)$$

In this phase, both the ideal discrimination S_1^* and the negative ideal discrimination S_1^- sets consist of elements as many as the number of decision points (i).

6) Calculation of Relative Closeness to Ideal Solution

The formula given in Equation 26, which utilizes from ideal and negative ideal separation measures, is used when calculating the relative closeness to ideal solution C_1^* for each decision point. In fact, the criterion used here express clearly the share of the negative ideal separation measure within the total separation measure.

$$C_i^* = \frac{S_i^-}{S_i^- + S_i^*} \quad (26)$$

Where; The C_1^* value takes a value in the range $0 \le C_1^* \le 1$ and $C_1^* = 1$ expresses the absolute closeness to the ideal solution of the relevant decision point and $C_1^* = 0$ expresses the absolute closeness to the negative ideal solution of the relevant decision point.

The decision maker will be able to select the closest decision point for optimal solution by ordering these values from large to small. In other words, this method allows the decision maker to rank the decision points taking into account the relative closeness to the optimal solution, and this method also provides a solution proposal for the decision maker [10].

III. Application

A. Determination of Selection Criteria and Alternatives

In order to determine the criteria to be used in evaluation before resolving the problem of weapon selection five main criteria were obtained that a result of wide participation brainstorming meetings held with the staff of the police center of district security department. Then, these five criteria were obtained namely "price", "weight", "safety system", "grip" and "mechanical structure".

In addition, the most popular weapon alternatives in this wide participation brainstorming meetings was suggested as "Option 1", "Option 2", "Option 3", "Option 4" and "Option 5". Since these are commercial trademarks and models, the names are not given in the study and they are named as individual “Option”s.

B. Calculation of Weights of Selection Criteria

The data from the decision makers from the decision makers were transferred to MS Excel 2010 program and we calculated the criterion weighting weights for each decision maker with AHP method.

At the end of the AHP method processing steps, I calculated and checked the $\mathbf{CR}$ value of the pairwise comparison matrices of each decision maker. Then I wanted them to recreate the pairwise comparison matrices by re-examining the decision-makers personal experience and value judgments for pairwise comparison matrices that do not satisfy $\mathbf{CR} \le \mathbf{0,10}$ condition.

From this, I obtained the pairwise comparison matrices for the single decision maker using the geometric mean method from the updated pairwise comparison matrices.

The AHP method is often preferred in solving multi-criteria decision making problems. In the process of calculating the consistency ratio of the AHP methods used in the literature, the random index table given in Table 2 is frequently preferred. However, in this study, the consistency ratio calculations of the AHP method were calculated using the formula given in Equation 14 developed by Taha [5].

The importance levels of the criteria after the calculations are given in TABLE III.

TABLE III. Importance Level of Criteria for AHP

1	Safety System	0,3866
2	Mechanical Structure	0,2687
3	Weight	0,2006
4	Grip	0,0861
5	Price	0,0579

As it can be understood from this, the most important criterion was determined as the "Safety System" criterion with the highest importance.

C. Ranking of Alternatives

In the previous phase, the criterion importance levels were obtained at the end of the AHP method processing steps. In this step, I calculated the TOPSIS method steps using MS Excel 2010 program again.

In the TOPSIS method, the initial decision matrix to be generated by the decision maker should be obtained as a scoring or value assignment rather than a pairwise comparison as in the AHP method [11].

For this reason, the TOPSIS Method initial decision matrix, which is based on the views of experts in the security sector, is shown in Table IV.

TABLE IV. Initial Decision Matrix for TOPSIS

Table IV	Price	Weight	Safety System	Grip	Mechanical Structure
Option 1	12500	945	3	12,50	2
Option 2	3150	834	3	17,67	2
Option 3	8000	998	2	12,50	1
Option 4	3000	1000	2	16,00	1
Option 5	20000	975	3	15,00	2

The most important point to be considered when determining the ideal and negative ideal solution set of the TOPSIS method is to investigate whether the evaluation factor concerned is benefit-based or loss-based and to calculate the solution process accordingly. Because the TOPSIS Method assumes that each evaluation factor has a monotonically increasing or monotonically decreasing trend [9].

Therefore, in this study, i accepted the "price" and "weight" criterion as loss-based criteria that are considered in the sequencing of alternatives using the TOPSIS method. Besides i also accepted the "safety system", "grip", "mechanical structure" criterion as benefit-based criteria.

TABLE V. Final Result for TOPSIS

Table V	S_i^*	S_i^-	Closeness	Ranking
Option 1	0,0276	0,0987	0,7815	2
Option 2	0,0003	0,1065	0,9972	1
Option 3	0,0999	0,0275	0,2159	5
Option 4	0,0984	0,0400	0,2890	4
Option 5	0,0417	0,0973	0,7000	3

I ordered the ideal solution approximation values obtained after the TOPSIS method steps from large to small.

As a result, in this study, “Option 2” was proposed as the best alternative for decision makers according to TOPSIS method, is shown in Table V.

IV. Conclusion

Findings from this study will enable decision makers to reduce work accidents due to unsuitable weapon selection for the working environment.

In addition, as a result of the evaluation of these results by the enterprises in the arms sector, enterprises will be able to gain competitive advantage in the market by increasing efficiency and productivity rates in the production processes and obtaining higher quality products.

References

[1] T. L. Saaty, “How To Make A Decision: The Analytic Hierarchy Process”, *European Journal of Operation Research*, Vol. 48(1), 1990, pp. 9–26.

[2] A. Supçiller, O. Çapraz, “AHP ve TOPSIS Yöntemine Dayalı Tedarikçi Seçimi Uygulaması”, *İstanbul Üniversitesi İktisat Fakültesi Ekonometri ve İstatistik Dergisi*, Vol. 13, 2011, pp. 1-22.

[3] T. L. Saaty, “Decision making with the analytic hierarchy process”, *International Journal of Services Sciences*, Vol. 1(1), 2008, pp. 83-93.

[4] A. Sarucan, “Yönetimde Analitik Karar Verme” , unpublished.

[5] H. A. Taha, *Yöneylem Araştırması*, İstanbul, Literatür Yayıncılık, Vol. 6, 2015, pp. 511-522.

[6] T. L. Saaty, (2018, April, 20), AHP and ANP (Group Decision) [Online], Available: https://superdecisions.com/method/index.php?section=GroupDecision.

[7] T. L. Saaty, L. T. Tran, “On The Invalidity of Fuzzifying Numerical Judgments in The Analytic Hierarchy Process”, *Mathematical and Computer Modelling*, Vol. 46 (7-8), 2007, pp. 962- 975.

[8] G.-H. Tzeng, J.-J. Huang, *Multiple Attribute Decision Making: Methods and Applications*, New York, Taylor & Francis Group, 2011, pp. 15-71.

[9] M. Arıbaş, U. Özcan, “Evaluation of Academic Research Projects Using AHP and TOPSIS Methods”, *Journal of Polytechnic*, Vol. 19 (2), 2015, pp. 163-173.

[10] S. Opricovic, G.-H. Tzeng, “Compromise Solution by MCDM Methods: A Comparative Analysis of VIKOR and TOPSIS”, *European Journal of Operational Research*, Vol. 156 (2), 2004, pp. 445-455.

[11] S. Uzun, H. Kazan, “Çok Kriterli Karar Verme Yöntemlerinden AHP TOPSIS ve PROMETHEE Karşılaştırılması: Gemi İnşada Ana Makine Seçimi Uygulaması”, *Journal of Transportation and Logistics*, Vol. 1 (1), 2016, pp. 99-113.

Muhammed Furkan Karaburun is currently a master student at Necmettin Erbakan University, Turkey. He was erasmus student in Industrial Engineering and Management at Instituto Superior Técnico of the Technical University of Lisbon, 2013-2014. Degree in Industrial Engineering at Selçuk University, Konya, 2015. His areas of research interests include multi-criteria decision making and operations research.

Kemal Alaykiran is currently working as an Assistant Professor at the Industrial Engineering Department of Necmettin Erbakan University (Konya, Turkey). He received the B.Sc., M.Sc., degrees in Industrial Engineering at Selcuk University and Ph.D. Degree in Industrial Engineering at Gazi University (Ankara, Turkey). His research interests are mathematical modeling, optimization and simulation of systems.