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Applicability of Fuzzy TOPSIS Method in Optimal Portfolio Selection and an Application in BIST

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Abstract

General structure of saving-investment cycle and the effectiveness of this structure are included in the most significant issues of the financial system. One of the points of intervention in providing an effective saving-investment cycle is possible through channeling the savings toward optimal investment fields. This study aims at detecting the existence of alternative methods in determining optimal selection combination in the risk and revenue perspective of individual and corporate investors who would like to evaluate their savings in capital markets. For this purpose, the applicability of Fuzzy TOPSIS method, one of the multi-criteria decision making techniques in optimal portfolio selection was researched. The applicability of the stock investment alternatives ranked according to Fuzzy TOPSIS method was examined by comparing them to the optimal selection results determined according to Markowitz, one of the modern portfolio management techniques. In the study where performance indexes were used as assessment criteria the results of both methods were discussed in terms of risk at a certain revenue level and revenue at a certain risk level through Johnson and Sharp Indexes. The results obtained determined that the Fuzzy TOPSIS portfolio alternatives created using Fuzzy TOPSIS method revealed quite positive results in terms of performance, revenue and risk and pointed at applicability of Fuzzy TOPSIS method in optimal portfolio selection as well.

Keywords: optimal portfolio selection, fuzzy TOPSIS, markowitz portfolio optimization method

1. Introduction

Lexical meaning of investment is "the money invested into an income-generating movable or immovable property" (http://tdkterim.gov.tr/bts/). As can be understood from the definition, to generate income, the deposit should be attached to an asset. Today, increased variety of options that the investors can attach their deposits to helps decrease the risks they face. Securities, which is one of these options, are now among the main investment instruments through which investors can use their deposits, obtain income, and distribute the risk by diversification. In this context, obtaining the desired return is closely related to the determination of the securities that will provide the highest return, or to the creation of an optimal portfolio that includes these securities.

The optimal portfolio is the choice of the security component that will provide the highest return at a certain risk level that the investor can bear. The portfolio selection that constitutes the decision phase of how an investor will distribute his or her wealth in a securities basket is a technical process that constitutes the third stage of portfolio management. The only determinant of the process is based on return and risk comparisons. Portfolio selection, which has become one of the most important area of study in modern finance, is referred to in the literature as Modern Portfolio theory, which is based on the pioneering work of Markowitz and Sharpe (Solimanpur et al., 2015; Ceylan & Korkmaz, 1998). The basic assumptions of the theory can be summarized as follows (Konuralp, 2005; Yoruk, 2000):

a) It is based on maximizing utility.

b) Hedging is based on diversification.

c) Expected return and risk are accepted as the main determinants of investor decisions.

d) Investors' risk and return expectations are homogeneous and based on the principle of maximization of the return at a certain risk level.

e) Efficient market conditions apply.

f) Investors have the identical time horizon.

Optimal portfolio selection in modern portfolio management, in which the relationship between the securities becomes prominent in terms of hedging, is mathematically calculated by quadratic programming and is called “effective portfolio”. Effective portfolios represent securities that have the highest return at the same risk level or that have the lowest risk at the same return level. The curve showing the effective portfolios at different risk and return levels is defined as the “Effective Boundary” and each security component along that boundary represents the optimal investment component for the investor (Karan, 2011).

Considering everything explained up to here, it is understood that to form an optimal portfolio and/or to select the securities to form an optimal portfolio is a decision process that is shaped primarily by risk and expected return. Cognitively, decision is defined in the Turkish Dictionary of the Turkish Language Society as *“the definite judgment reached by thinking about a job or a problem”* (http://tdkterim.gov.tr/bts/); whereas in terms of business management, decision is defined as *“the choice the manager or any other person makes in any subject”* (Kocel, 2005). In essence, the gist of decision making is the pursuit of; *“choosing the most suitable or the most appropriate one among the choices after thinking thoroughly on a subject”*(Ulgen & Mirze, 2010). Similar to all decision-making processes, there are many alternatives for investors who are also decision makers in the selection of optimal portfolios, and there are quite a number of decision criteria that can be used to evaluate these alternatives. No doubt, within the scope of this study, what is meant by alternatives is the securities, and what is meant by decision criteria is the financial ratios.

Particularly in the field of business management, techniques called multi-criteria decision making methods are frequently used by researchers for solution, when there are a large number of decision criteria and also problems about decision making that require consideration of a large number of alternatives. Some of these techniques only allow the use of the quantitative data whereas some allow the use of both qualitative and quantitative data. Among these techniques TOPSIS, which is one of the traditional multi-criteria decision making methods, focuses on identifying and choosing the alternative that is farthest from the negative ideal solution and closest to the positive ideal solution (Deng et al., 2000); it is a ranking methodology developed by Hwang and Yoon in 1981 (Hsu et al., 2015); and it comprises 6 steps, which are: calculating the normalized decision matrix, calculating the weighted normalized decision matrix, determining the positive and negative ideal solutions, calculating the distribution measures, calculating the proximity to the ideal solution, and the decision criteria should be measurable and comparable (Chen & Hwang, 1992).

Traditional multi-criteria decision making techniques, which also include TOPSIS, can be inadequate for the types of problems encountered in real life. While this inadequacy can be due to the use of linguistic expressions by those who are at the position of decision making in the evaluation of alternatives or decision points, it can also be due to the classical logic based resolution algorithm of traditional multi-criteria decision making techniques. To eliminate these deficiencies, when evaluating the decision points based on the decision criteria, in addition to use linguistic expressions such as “very poor”, “poor”, “medium poor”, “fair”, medium good”, “good” and “very good”, the use of fuzzy logic instead of classical logic can provide great convenience to the researchers at the point of resolution. While linguistic expressions are highly advantageous when decision criteria have subjectivity or where past experience of decision makers is important for evaluation, the use of fuzzy logic shows a structure suitable for problems encountered in real life by allowing some relationships that can not be included in the membership function according to classical logic to be included in the solution process (Chen, 2000).

In the Fuzzy Logic Theory developed by Luftu-zade in 1965 (Altas, 1999), contrary to classical logic, a member's membership relation to the relevant set is determined using a scale that includes intermediate values or expressions instead of definitive values or expressions, and the probability of occurrence of fuzzy states can be determined (Vural, 2002). Since the fuzzy logic is more useful than classical logic and the expertise, past experience and future expectations of decision makers must be taken into consideration in order to solve the type of problem handled in this study, Fuzzy TOPSIS method, which includes the superior aspects of fuzzy logic and traditional TOPSIS method, is used.

Fuzzy TOPSIS method has been used to solve many different problems in the field of business management. In this context, before explaining the algorithm of the method, summary of some of the studies in which Fuzzy TOPSIS was used is provided in Table 1.

Table 1. Summary information on some of the studies in which fuzzy TOPSIS method was used

Author(s)	Year	Topic
Chen	2000	Selection of system analysis engineer
Chen	2001	Selection of location for distribution center
Tsao	2003	Assessment of equity investments
Bottani and Rizzi	2006	Third party logistics service provider choice
Chen et al.	2006	Supplier evaluation and selection
Yong	2006	Site selection
Ecer	2006	Sales staff assessment
Dundar et al.	2007	Evaluation of web sites of virtual stores
**Ecer	2007	Choosing a store location
Ecer	2007	Sales staff assessment and selection
Eleren and Ersoy	2007	Evaluation of marble block cutting methods
Kahraman et al.	2007	Logistics information technology
Ozdemir ve Secme	2009	Strategic supplier choice
Mahdi and Hossein	2008	Project and contractor selection
Onut and Soner	2008	Location selection
Ozturk et al.	2008	Choosing a transportation company
Salehi and Moghaddam	2008	Project evaluation and selection
Ecer et al.	2009	Optimal portfolio selection
Kucuk and Ecer	2009	Supplier choice
Gokdalay and Evren	2009	Airport performance evaluation
Shahanaghi and Yazdian	2009	Supplier choice
Sun and Lin	2009	Evaluation of Web Based Shopping Sites
Bagheri and Tarokh	2010	Supplier choice
Tirmikcioglu and Cinar	2010	Site selection
Erginel et al.	2010	GSM Sector
Tan et al.	2010	Construction project selection
Baskaya and Ozturk	2011	Sales staff selection
Eraslan and Tansel	2011	Investment region selection
Eleren and Yilmaz	2011	Selection of supplier for textile firm
Erkayman et al.	2011	Logistics center location selection
Madi and Tap	2011	Investment boards choice
Mangir and Erdogan	2011	Analysis of economic performances of countries
Ozcakar and Demir	2011	Supplier choice
Ashrafzadeh et al.	2012	Warehouse location selection
Awasthi and Chauhan	2012	Sustainable city logistics planning
Buyukozkan and Cifci	2012	Choice of green suppliers
Huang and Peng	2012	Evaluation of the competitive structure of tourism industry
Paksoy et al.	2012	Development of organizational strategy in distribution channel management
Uysal and Tosun	2012	Selection of computerized maintenance management system
Yayla et al.	2012	Supplier choice
Alemi and Akram	2013	Evaluation of the leanness of manufacturing systems
Sedaghat	2013	Productivity development in the banking sector
Kahraman et al.	2013	Evaluation of investment alternatives in the field of education
Maity and Chakraborty	2013	Material selection
Prascevic and Prascevic	2013	Evaluation of optimal alternatives for resource conservation
Sari	2013	RFID technology selection
Vatansever	2013	Supplier choice
Uludag and Deveci	2013	Supplier choice
Uludag and Deveci	2013	Site Selection
Mahdevari et al.	2014	Occupational health and safety

Mokhtari et al.	2014	Selection of best well control system
Yildiz and Yildiz	2014	ERP software selection
Ardakani et al.	2015	Evaluation of service quality
Chen and Lu	2015	Evaluation of competitive structures of insurance companies
Kabra and Ramesh	2015	Humanitarian supply chain management
Arslan and Yildiz	2015	Site selection for sports schools
Gul and Uludag	2016	Choosing a charismatic leader
Akyuz and Kilinc	2016	Site selection for a private hospital

2. Mathematical Form of Fuzzy TOPSIS Method

Although basic stages of the Fuzzy TOPSIS method is the same as the traditional TOPSIS method, its requirement of some special calculations in terms of mathematics makes it slightly operationally complicated. The main stages of the method are presented below in a manner similar to the studies previously shown in Table 1.

Stage 1: In the first phase, the "d" number of decision makers, an ensemble of the group of experts, decision criteria, and identification of alternatives must be defined. In this context, a group of decision makers was formed. "j" represents decision criteria, "i" represents the alternatives; and of 21 decision criteria, 15 alternatives were chosen to be used. According to this, $d = (1, 2 ,3)$, $j = (1, 2, \dots, p)$ and $i = (1, 2, \dots, q)$.

Stage 2: In the second stage, the linguistic variables necessary for the weighting of the criteria and for the evaluation of the alternatives according to the criteria should be determined. The linguistic variables to be used in this context and their corresponding triangular fuzzy numbers are determined and shown in Table 2.

Table 2. Linguistic variables and corresponding triangular fuzzy numbers

Weighting of the Criteria		Ratings of Alternatives	
Variable	Triangle Fuzzy Number	Variable	Triangle Fuzzy Number
Very Low (VL)	(0, 0, 0.1)	Very Poor (VP)	(0, 0, 1)
Low (L)	(0, 0.1, 0.3)	Poor (P)	(0, 1, 3)
Medium Low (ML)	(0.1, 0.3, 0.5)	Medium Poor (MP)	(1, 3, 5)
Medium(M)	(0.3, 0.5, 0.7)	Fair (F)	(3, 5, 7)
Medium High (MH)	(0.5, 0.7, 0.9)	Medium Good (MG)	(5, 7, 9)
High (H)	(0.7, 0.9, 1)	Good (G)	(7, 9, 10)
Very High (VH)	(0.9, 1, 1)	Very Good (VG)	(9, 10, 10)

Sourse: Chen, 2000.

Stage 3: In the third stage expert opinions are collected for the weighting of the criteria and grading the alternatives.

Stage 4: In this stage, the weights of the criteria and the importance ratings of the alternatives according to the criteria are calculated by the mathematical formulas shown in equations (1) and (2) respectively. In the equations, "d" represents the experts, "i" the alternatives, and "j" the decision criteria $(d = 1, 2, 3;\ i = 1, \dots, p \ and \ j = 1, \dots, q)$.

$$\tilde{h}_j = \frac{1}{d}\left[\left(\tilde{h}_j^1\right) + \left(\tilde{h}_j^2\right) + \left(\tilde{h}_j^3\right)\right] \tag{1}$$

$$\tilde{t}_{ij} = \frac{1}{d}\left[\left(\tilde{t}_{ij}^1\right) + \left(\tilde{t}_{ij}^2\right) + \left(\tilde{t}_{ij}^3\right)\right] \tag{2}$$

Stage 5: In the fifth stage, fuzzy initial decision matrix indicated as "$\tilde{S}$" and fuzzy weight decision matrix indicated as "$\tilde{H}$" are generated.

$$\tilde{S} = \begin{bmatrix} t_{11} & \dots & t_{1i} \\ \dots & \dots & \dots \\ t_{j1} & \dots & t_{ij} \end{bmatrix} \ (i = 1, 2, \dots, p) \ ve \ (j = 1, 2, \dots, q) \tag{3}$$

$$\tilde{H} = \left[\tilde{h}_1, \tilde{h}_2, \dots, \tilde{h}_j\right] \qquad (j = 1, 2, \dots, q) \tag{4}$$

Stage 6: In the sixth stage, a normalized decision matrix, represented by equation (5), is generated. Here, $t_{ij} = \left(x_{ij}, y_{ij}, z_{ij}\right)$ is a triangular fuzzy number and "F" represents a benefit, "M" represents a cost:

$$G = [\tilde{g}_{ij}]_{pxq} \quad (i = 1, 2, \dots, p)\ ve\ (j = 1, 2, \dots, q) \tag{5}$$

$$\tilde{g}_{ij} = \left(\frac{x_{ij}}{z_j^*}, \frac{y_{ij}}{z_j^*}, \frac{z_{ij}}{z_j^*}\right) \qquad j \in F$$

$$\tilde{g}_{ij} = \left(\frac{x_j^-}{z_{ij}}, \frac{x_j^-}{y_{ij}}, \frac{x_j^-}{x_{ij}}\right) \qquad j \in M$$

$$z_j^* = \underbrace{max}_{i}\ z_{ij} \qquad j \in F$$

$$x_j^- = \underbrace{min}_{i}\ x_{ij} \qquad j \in M$$

Stage 7: In the seventh stage, weighted normalized fuzzy decision matrix represented as "$\widetilde{W}$" and shown in Equation (6) is formed.

$$\widetilde{W} = [\widetilde{w}_{ij}]_{pxq} \qquad (i = 1, 2, \dots, p)\ ve\ (j = 1, 2, \dots, q) \tag{6}$$

In this equation (6):

$$\widetilde{w}_{ij} = \tilde{g}_{ij}(.)\tilde{h}_{ij} \qquad (\widetilde{w}_{ij}, \forall i, j)$$

Stage 8: In this stage, the Fuzzy Positive Ideal Solution (FPIS, U^*) shown in equation no (7) and Fuzzy Negative Ideal Solution (FNIS, U^-) shown in equation no (8) are calculated.

$$U^* = (\widetilde{w}_1^*, \widetilde{w}_2^*, \widetilde{w}_3^*, \dots, \widetilde{w}_j^*) \tag{7}$$

$$U^- = (\widetilde{w}_1^-, \widetilde{w}_2^-, \widetilde{w}_3^-, \dots, \widetilde{w}_j^-) \tag{8}$$

$$\widetilde{w}_j^* = (1,1,1) \qquad (j = 1, 2, \dots, q)$$

$$\widetilde{w}_j^- = (0,0,0)$$

Stage 9: The relative distances of each alternative from the values of FPIS and FNIS are calculated with the help of Equations (9) and (10), respectively. In the equations, $v(.,.)$ represents the distance between two triangular fuzzy numbers (Chen, 2000; Ecer, 2006).

$$v_i^* = \sum_{j=1}^{q} v(\widetilde{w}_{ij}, \widetilde{w}_j^*) \ \ (i = 1,2, \dots, p) \tag{9}$$

$$v_i^- = \sum_{j=1}^{q} v(\widetilde{w}_{ij}, \widetilde{w}_j^-) \ \ (i = 1,2, \dots, p) \tag{10}$$

Stage 10: The proximity coefficient (PC) for each alternative is calculated by the formula shown in Equation (11) and the alternatives are sorted according to the proximity coefficients.

$$PC = \frac{v_i^-}{v_i^* + v_i^-} \tag{11}$$

3. An Application for Optimal Portfolio Selection

In this part of the study, a pool of all stocks offered by various brokerage houses for investors was created, then the common stocks were selected and sorted according to the Fuzzy TOPSIS method. A portfolio was created according to the ranking, and the performance of the portfolio was determined and compared with the performance of the portfolio constructed according to the traditional portfolio theory. In this way, the applicability of Fuzzy TOPSIS method in optimal portfolio selection has been tried to be determined.

3.1 Ranking of Alternatives According to Fuzzy TOPSIS Method

The general view of the optimal portfolio selection problem, which is to be solved by the fuzzy TOPSIS method, is as shown in Figure 1; and according to the Fuzzy TOPSIS Method algorithm presented in section two, the solution is shown stage by stage.

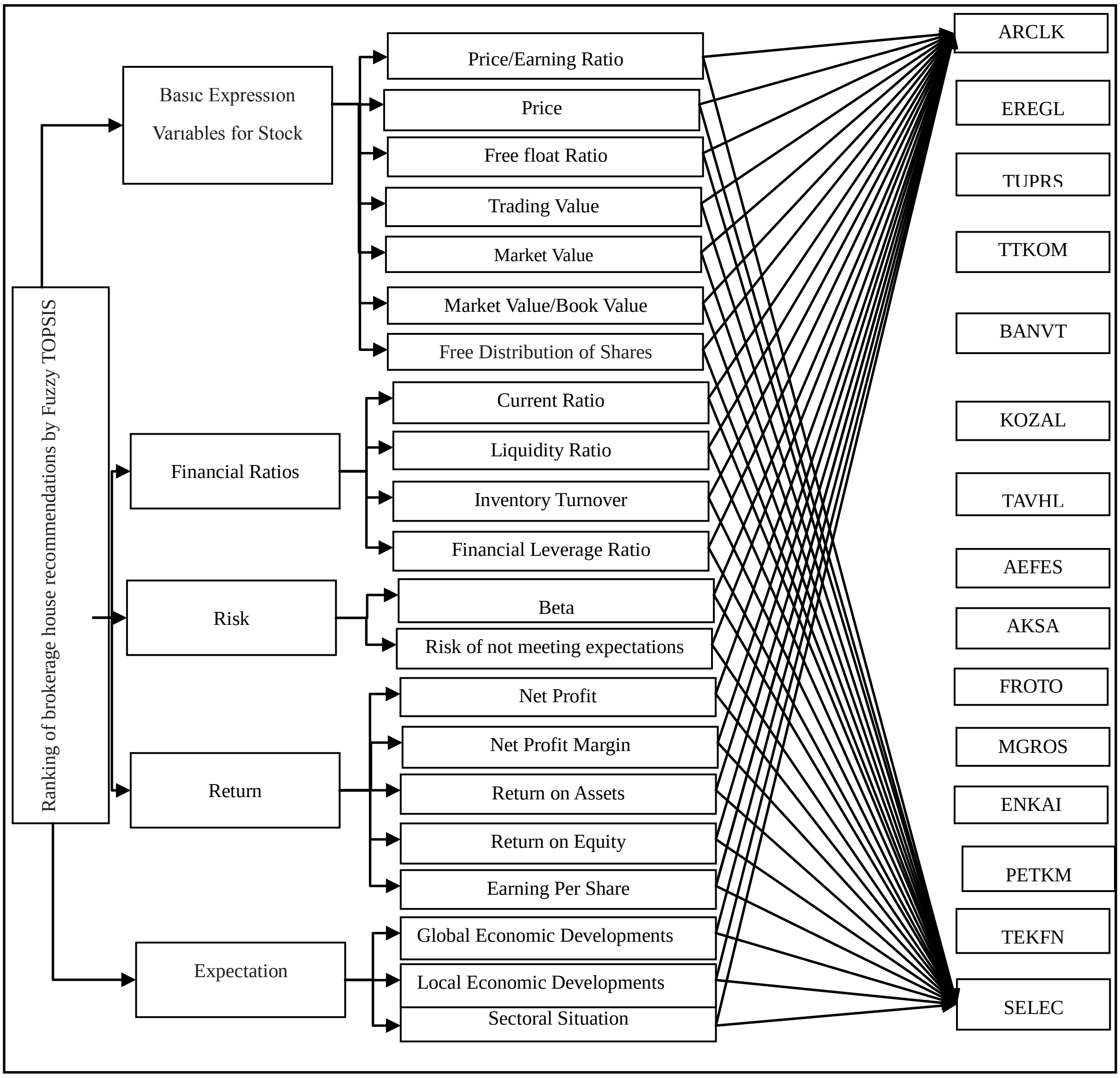

Figure 1. The usege of the optimal portfolio selection in fuzzy TOPSIS method

Stage 1: Due to the method's essence, a decision-maker group must be formed from those who are experts in stock investments. In this context, investment advisors who are experts on stock investments in portfolio management companies and people who are also experts in these areas have been requested to provide their evaluations. A three person decision making group consisting of two expert portfolio managers and one academician who received a favorable response on the basis of the negotiations was established. Therefore, the number of decision makers constituting the basis of this stage, (d), was determined as 3. After the formation of the decision making group**,** the final decision on the criteria determined according to the literature was made on the basis of the interviews with the decision makers. In this context; The main explanatory variables of the stock were grouped under five main headings as “basic expression variables for stock”, “financial ratios”, “risk”, “return” and “expectation” and a total of 21 sub-decision criteria grouped under these main headings were determined. Following this, the stocks that are common among the stocks recommended by the brokerage houses, that is, 15 stocks recommended by all brokerage houses, were determined as the decision points, or in other words, as alternatives. Table 3 below shows the decision criteria used to evaluate the alternatives and the explanations, and Table 4 shows the decision points.

Table 3. Decision criterias and description group

Description Group	The Name of Decision Criteria	No
THE MAIN EXPLANATORY VARIABLES	Price / Profit Rate	C1
	Price	C2
	Free Float Ratio	C3
	Trading Volume	C4
	Market Value	C5
	Market Value/Book Value	C6
	Free Distribution of Shares	C7
LIQUIDITY AND FINANCIAL STRUCTURE	Current Ratio	C8
	Liquidity Ratio	C9
	Inventory Turnover	C10
	Financial Leverage Ratio	C11
RISK	Beta	C12
	Risk of not meeting expectations	C13
RETURN	Net Profit	C14
	Net Profit Margin	C15
	Return on Assets	C16
	Return on Equity	C17
	Earning Per Share	C18
EXPECTATION	Global Economic Developments	C19
	Local Economic Developments	C20
	Sectoral Situation	C21

Table 4. The decision points

Stock Name	Stock No	Stock Name	Stock No	Stock Name	Stock No
ARCLK	A1	KOZAL	A6	MGROS	A11
EREGL	A2	TAV HL	A7	ENKAI	A12
TUPRS	A3	AEFES	A8	PETKM	A13
TTKOM	A4	AKSA	A9	TEKFN	A14
BANVT	A5	FROTO	A10	SELEC	A15

Stage 2: After establishing the decision making group, determining decision criteria and alternatives, appropriate linguistic variables and their corresponding fuzzy numbers have been determined to evaluate the criteria and alternatives. At this stage, Chen's study has been accepted as a reference, and the linguistic variables used in Table 2 previously mentioned in the second chapter and their corresponding triangular fuzzy numbers are shown.

Stage 3: In this stage, opinions of experts on decision criteria and points were collected through linguistic variables shown in Table 2.

Stage 4: In this stage, the weight of the criteria and the significance ratings of the alternatives are calculated using the formulas shown in equations (1) and (2), where the algorithm of the Fuzzy TOPSIS method is shown.

The linguistic evaluations that experts use for decision criteria and alternatives were fuzzed using the triangular fuzzy numbers shown in Table 2. The calculations for fuzzing the linguistic variables are shown in Tables 5 and 6 below only for decision criterion (C1) and decision point (A6), respectively.

Table 5. Blurring linguistic variables for decision criteria (C1)

		C1		
Decision Makers (DM)	Linguistic Variable	x	y	Z
DM1	MH	0.5	0.7	0.9
DM2	VH	0.9	1.0	1.0
DM3	H	0.7	0.9	1.0
Average		**0.7**	**0.866667**	**0.966667**

"C1: Price / Profit Ratio" Calculation of Weight of Decision Criteria:

$\tilde{h}_1 = (0.5+0.9+0.7)/3 = 0.7$

$\tilde{h}_1$= (0.7+1.0+0.9)/3 = 0.866667

$\tilde{h}_1$= (0.9+1.0+1.0)/3 = 0.966667

$\tilde{h}_1$= (0.7; 0.866667; 0.96667)

$\tilde{h}_1$= (0.7; 0.866667; 0.96667)

Table 6. Determining the significance of the decision point (A6) and blurring it

		C1		
Decision Makers	Linguistic Variable	Low	Medium	Upper
DM1	MG	5	7	9
DM2	MP	1	3	5
DM3	G	7	9	10
Average		**4.3333**	**6.3333**	**8**

Determination of the Degree of Importance of "A6: Koza Gold Decision Point" According to "C1: Price / Profit Rate" and Fuzzing:

$\tilde{t}_{61}$ = (5+1+7)/3 = 4.3333;

$\tilde{t}_{61}$ = (7+3+9)/3 = 6.3333;

$\tilde{t}_{61}$ = (9+5+10)/3 = 8

$\tilde{t}_{61}$ = (4.3333; 6.3333; 8.0000)

Stage 5: In this stage, the fuzzy decision and fuzzy weight matrices are shown by equations (3) and (4) at the part where the algorithm of Fuzzy TOPSIS method is. The fuzzy decision matrix, represented by, $\tilde{S}$ is not shown because it was too large. The resulting fuzzy weight matrix is shown in Table 7.

Table 7. Fuzzy weight matrix

	Tringular Fuzzy Number				Tringular Fuzzy Number		
Criteria	x	y	z	Criteria	x	y	z
C1	0.700000	0.866667	0.966667	C12	0.466667	0.633333	0.766667
C2	0.466667	0.600000	0.700000	C13	0.433333	0.633333	0.833333
C3	0.266667	0.433333	0.633333	C14	0.333333	0.466667	0.633333
C4	0.633333	0.800000	0.933333	C15	0.500000	0.700000	0.900000
C5	0.700000	0.866667	0.966667	C16	0.566667	0.766667	0.933333
C6	0.700000	0.866667	0.966667	C17	0.700000	0.866667	0.966667
C7	0.266667	0.433333	0.633333	C18	0.700000	0.866667	0.966667
C8	0.266667	0.400000	0.566667	C19	0.566667	0.733333	0.833333
C9	0.266667	0.400000	0.566667	C20	0.566667	0.733333	0.833333
C10	0.266667	0.400000	0.566667	C21	0.633333	0.800000	0.900000
C11	0.566667	0.733333	0.866667				

Stage 6: In the sixth stage values normalized based on the fuzzy decision matrix were calculated and normalized fuzzy decision matrix, shown in equation (5) at the part where Fuzzy TOPSIS method algorithm is, was generated. The normalized fuzzy decision matrix cannot be shown due to its size; only the normalization process of "A6: Koza Gold" decision point according to "C1: Price / Profit Rate" was given below.

$\tilde{g}_{61}$ = (4.3333 / 8.66667; 6.3333 / 8.66667; 8 / 8.66667)

$\tilde{g}_{61}$= (0.5; 0.73; 0.92)

Stage 7: In this stage, the weighted normalized fuzzy values were calculated using the normalized fuzzy decision matrix generated in the sixth stage, and a weighted normalized fuzzy decision matrix represented by $\widetilde{W}$ in Equation (6) was generated but could not be shown due to its size. As an example of the calculation of the weighted normalized values, only the weighted normalization process of "A6: Koza Gold" alternative to "C1: Price/Profit Rate" was shown.

Calculation of Weighted Normalized Value of "A6: Koza Gold" Alternative by "C1: Price / Profit Rate":

$\tilde{g}_6$= (0.5; 0.73; 0.92)

$\tilde{h}_1$= (0.7; 0.866667; 0.96667)

$\tilde{w}_{61}$ = (0.5*0.7; 0.73*0.866667; 0.92*0.966667)

$\tilde{w}_{61}$= (0.35; 6.33; 0.89)

Stage 8: In the eighth stage, Fuzzy Positive value represented as (U^*) in Equation (7) and Negative Ideal Solution values represented as (U^-) in Equation (8) were calculated and shown in Tables 8 and 9, respectively.

Table 8. FPIS values (U^*)

	Decision Points														
Criteria	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15
C1	0.41	0.55	0.37	0.32	0.93	0.37	0.36	0.42	0.37	0.37	0.93	0.32	0.32	0.41	0.37
C2	0.35	0.31	0.38	0.28	0.50	0.31	0.28	0.35	0.38	0.35	0.59	0.28	0.31	0.38	0.28
C3	0.34	0.39	0.30	0.30	0.38	0.39	0.34	0.30	0.29	0.39	0.43	0.34	0.30	0.32	0.32
C4	0.54	0.37	0.59	0.41	0.85	0.68	0.33	0.54	0.50	0.50	0.64	0.33	0.65	0.68	0.55
C5	0.55	0.59	0.70	0.72	0.70	0.37	0.42	0.50	0.41	0.33	0.40	0.45	0.45	0.32	0.50
C6	0.33	0.37	0.33	0.47	0.74	0.42	0.56	0.12	0.52	0.47	0.69	0.62	0.34	0.52	0.62
C7	0.43	0.44	0.36	0.32	0.41	0.41	0.35	0.35	0.37	0.40	0.41	0.43	0.41	0.38	0.38
C8	0.37	0.47	0.30	0.30	0.39	0.30	0.25	0.32	0.39	0.32	0.34	0.41	0.42	0.37	0.32
C9	0.35	0.47	0.27	0.29	0.47	0.33	0.33	0.42	0.42	0.31	0.35	0.45	0.44	0.29	0.29
C10	0.32	0.26	0.37	0.35	0.39	0.37	0.37	0.29	0.35	0.30	0.35	0.46	0.30	0.32	0.35
C11	0.43	0.42	0.47	0.47	0.42	0.39	0.43	0.35	0.42	0.39	0.39	0.47	0.39	0.39	0.47
C12	0.33	0.33	0.33	0.33	0.41	0.33	0.37	0.32	0.40	0.37	0.37	0.53	0.33	0.33	0.33
C13	0.47	0.43	0.43	0.43	0.40	0.47	0.47	0.43	0.47	0.40	0.47	0.47	0.47	0.40	0.47
C14	0.34	0.40	0.45	0.35	0.61	0.37	0.32	0.45	0.32	0.29	0.61	0.40	0.46	0.29	0.34
C15	0.44	0.44	0.40	0.40	0.87	0.71	0.40	0.51	0.40	0.37	0.87	0.51	0.63	0.51	0.55
C16	0.42	0.44	0.34	0.44	0.90	0.57	0.48	0.48	0.37	0.34	0.90	0.57	0.41	0.57	0.61
C17	0.35	0.34	0.47	0.61	0.94	0.61	0.42	0.52	0.33	0.30	0.94	0.56	0.33	0.61	0.71
C18	0.51	0.56	0.56	0.72	0.94	0.65	0.51	0.72	0.23	0.42	0.91	0.75	0.52	0.51	0.83
C19	0.35	0.35	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39
C20	0.31	0.35	0.35	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39
C21	0.33	0.37	0.37	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41
Total	**8.26**	**8.66**	**8.53**	**8.71**	**12.43**	**9.24**	**8.18**	**9.20**	**8.14**	**7.80**	**11.78**	**9.53**	**8.68**	**8.79**	**9.48**

Table 9. FNIS values (U^-)

	Decision Points														
Criteria	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15
C1	0.66	0.49	0.68	0.75	0.06	0.68	0.67	0.62	0.68	0.68	0.06	0.73	0.73	0.66	0.68
C2	0.41	0.45	0.37	0.50	0.22	0.45	0.50	0.41	0.36	0.41	0.14	0.50	0.45	0.38	0.50
C3	0.33	0.26	0.38	0.38	0.28	0.26	0.33	0.38	0.39	0.26	0.22	0.33	0.38	0.36	0.36
C4	0.46	0.67	0.41	0.62	0.13	0.28	0.71	0.46	0.51	0.51	0.37	0.71	0.32	0.32	0.46
C5	0.41	0.36	0.25	0.21	0.25	0.58	0.52	0.45	0.55	0.62	0.56	0.52	0.50	0.66	0.46
C6	0.70	0.65	0.70	0.53	0.26	0.59	0.39	0.26	0.49	0.53	0.31	0.37	0.66	0.49	0.37
C7	0.22	0.17	0.33	0.37	0.21	0.21	0.29	0.29	0.28	0.24	0.21	0.22	0.24	0.29	0.25
C8	0.25	0.12	0.32	0.32	0.22	0.32	0.39	0.30	0.21	0.3	0.27	0.19	0.17	0.25	0.30
C9	0.27	0.13	0.38	0.36	0.13	0.30	0.29	0.18	0.18	0.32	0.27	0.16	0.16	0.35	0.36
C10	0.29	0.37	0.22	0.26	0.20	0.23	0.22	0.31	0.26	0.32	0.26	0.12	0.32	0.29	0.26
C11	0.37	0.35	0.30	0.32	0.35	0.42	0.37	0.46	0.35	0.42	0.40	0.32	0.40	0.42	0.32
C12	0.48	0.48	0.48	0.48	0.38	0.48	0.44	0.47	0.38	0.43	0.44	0.25	0.48	0.48	0.48
C13	0.35	0.39	0.39	0.39	0.44	0.35	0.35	0.39	0.35	0.44	0.35	0.35	0.35	0.44	0.35
C14	0.38	0.31	0.23	0.37	0.04	0.34	0.40	0.23	0.40	0.44	0.04	0.30	0.23	0.44	0.38
C15	0.57	0.58	0.62	0.62	0.05	0.25	0.62	0.49	0.62	0.65	0.05	0.49	0.34	0.49	0.44
C16	0.60	0.60	0.71	0.60	0.05	0.45	0.55	0.55	0.67	0.71	0.05	0.45	0.63	0.45	0.40
C17	0.69	0.71	0.57	0.43	0.06	0.43	0.63	0.52	0.73	0.77	0.06	0.48	0.73	0.43	0.32
C18	0.53	0.48	0.48	0.32	0.06	0.37	0.53	0.32	0.81	0.64	0.09	0.27	0.52	0.53	0.18
C19	0.38	0.38	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33
C20	0.39	0.35	0.35	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31
C21	0.41	0.38	0.38	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33
Total	**9.15**	**8.68**	**8.89**	**8.77**	**4.36**	**7.98**	**9.18**	**8.05**	**9.20**	**9.67**	**5.14**	**7.73**	**8.59**	**8.69**	**7.84**

Stage 9: In this stage, at the part where the algorithm of the method is explained, the distance of the decision points to FPIS values represented as (v_i^*) in Equation (9) and FNIS values represented as (v_i^-) in Equation (10) were calculated and shown in Table 10.

Stage 10: The distances calculated with the formulas in Equations (9) and (10) are used in the formula shown in the formula depicted as equation (11) in the part where the algorithm of the method is included and the proximity coefficient of each decision point was calculated (PC_i). The calculation of the proximity coefficient of the "A6: Koza Gold" decision point alone is shown below; calculated proximity coefficients of other decision points and the ranking based on these coefficients are given in Table 10.

PC_6= 9.15/(8.26+9.15) PC_6= 0.5255

Table 10. Proximity coefficients of decision points and ranking according to these coefficients

Alternative Name	Alternative No	V_i^*	V_i^-	PC_i	Ranking
FROTO	A10	7.797.825	9.666.975	0.553512	1
AKSA	A9	8.138.807	9.201.987	0.530655	2
TAVHL	A7	8.183.940	917.706	0.528602	3
ARÇLK	A1	8.258.738	9.146.915	0.525514	4
TUPRS	A3	8.533.223	8.886.848	0.510150	5
TTKOM	A4	8.714.264	8.771.089	0.501625	6
EREGL	A2	8.656.875	8.675.879	0.500548	7
PETKM	A13	8.681.925	8.587.755	0.497274	8
TEKFN	A14	8.788.336	8.685.542	0.497059	9
AEFES	A8	9.197.002	8.045.323	0.466603	10
KOZAL	A6	9.242.565	7.976.255	0.463229	11
SELEC	A15	9.479.200	7.843.796	0.452797	12
ENKAI	A12	9.528.863	7.729.558	0.447872	13
MGROS	A11	11.777.610	5.141.970	0.303907	14
BANVT	A5	12.433.540	4.359.575	0.259605	15

In Figure 2, the ranking of decision points according to the proximity coefficients is shown in graph.

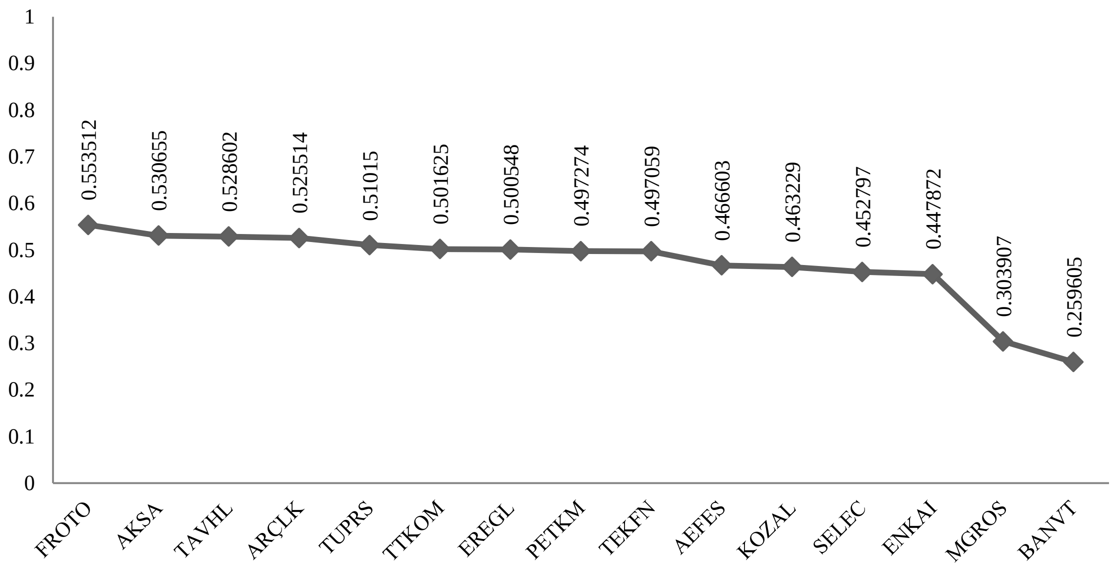

Figure 2. Ranking according to proximity coefficients of decision points

According to the results obtained through the evaluation of stocks recommended by brokerage houses via Fuzzy TOPSIS method, 15 stocks that are subjects of this study are sorted in the form of FROTO>AKSA> TAV HL > ARCLK > TUPRS > TTKOM > EREGL> PETKM > TEKFN >AEFES > KOZAL > SELEC > ENKAI >

MGROS > BANVIT. In addition, the results revealed that the decision makers consider the criteria C5, C18, C1, C6 and C17 significant when evaluating the stocks. Ranking of the 21 decision criteria in their order of importance according to the decision makers is shown in Table 11.

Table 11. Order of importance according to decision makers of decision criteria

Criteria No	Criteria Name	Order of Imp.	Criteria No	Criteria Name	Order of Imp.
C5	Market Value	1	C15	Net Profit Margin	7
C18	Earning Per Share	1	C13	Risk of not meeting expectations	8
C1	Price/Earning Ratio	1	C12	Beta	9
C6	Market Value/Book Value	1	C2	Price	10
C17	Return on Equity	1	C14	Net Profit	11
C4	Trading Volume	2	C3	Free Float Ratio	12
C21	Sectoral Situation	3	C7	Free Distribution of Shares %	12
C16	Return on Assets	4	C8	Current Ratio	13
C11	Financial Leverage Ratio	5	C9	Liquidity Ratio	13
C19	Global Economic Developments	6	C10	Inventory Turnover	13
C20	Local Economic Developments	6			

3.2 Portfolio Creation According to the Ranking Obtained from the Fuzzy TOPSIS Method

While creating the portfolio based on listings of the investment recommendations of the brokerage houses determined in accordance with the Fuzzy TOPSIS method, in order to calculate the diversification and weights of the stocks to be included in the portfolio, PC_i value of each stock has been deducted from Average PC_i Based on these differences, the alternatives of bipartite, tripartite, quadripartite stock certificates that are the basis of diversification are determined. Portfolio weights of each alternative are calculated as a percentage of these differences. The determined portfolios and the weights of their components are shown in Table 12.

Table 12. Portfolios and components of fuzzy TOPSIS method

Stock Name	PC_i	PC_{i} - APC_i	Weights of Portfolio and Portfolio Components				
			6's (%)	5's (%)	4's (%)	3's (%)	2's (%)
FROTO	0.553512	0.084249	25.1881	27.8862	32.2508	41.1011	57.8471
AKSA	0.530655	0.061392	18.3545	20.3205	23.5010	29.9502	42.1529
TAVHL	0.528602	0.059339	17.7407	19.6410	22.7151	28.9486	
ARÇLK	0.525514	0.056251	16.8174	18.6189	21.5330		
TUPRS	0.510150	0.040887	12.2240	13.5334			
TTKOM	0.501625	0.032362	9.6753				
EREGL	0.500548	0.031285					
PETKM	0.497274	0.028011					
TEKFN	0.497059	0.027796					
AEFES	0.466603	-0.002660					
KOZAL	0.463229	-0.006030					
SELEC	0.452797	-0.016470					
ENKAI	0.447872	-0.021390					
MGROS	0.303907	-0.165360					
BANVT	0.259605	-0.209660					
Avarege (APC_i)	**0.469263**						

3.2.1 Determining Risk, Profit and Performance of Portfolios Created

The risk, return and performance indexes for alternative portfolios with different component numbers are calculated based on the PC ranking obtained from the decision criteria as shown in Table 12. The basis of the calculation were the average prices of the stock certificates in the brokerage house recommendations between 01.01.2010-01.03.2017 and were obtained from BIST.

In calculations made with Excel Solver, Markowitz's Modern Portfolio Theory criteria were taken as the portfolio model. The explanations for the operations carried out in this context are briefly as follows:

Return: Is the percentage change in the stock certificate within a certain period and is calculated by the formula $\frac{p_{n+1}}{p_n} - 1$. Return calculation is to determine the net capital gain or loss that the stock investment shows.

Portfolio Return: The future course of financial assets is based on the assumption that it will exhibit its past performance and refers to the weighted average of the expected return of a stock certificate by its proportion in the portfolio. The formula used in the calculations is shown in equation (12) (Aksoy & Tanrıoven, 2007).

$$R_p \;=\; \sum_{i=1}^{n} R_i x_1 = R_i x_1 + R_2 x_2 + \cdots . + R_n x_n \tag{12}$$

$$\sum_{i=1}^{n} x_i = x_1 + x_2 + \;\dots\dots\dots\dots\dots . + x_n = 1 \; ve \; 0 \le x \quad i \le 1$$

Risk: Risk is the probability of facing an undesired event or effect in the future and represents the standard deviation that shows the probability of having less return than expected. The formula used in the calculations is shown in equation (13) (Aksoy & Tanrıoven, 2007).

$$\sigma_p = \sqrt{\sum_{i=1}^{n} x_i^2 \sigma_i^2 + 2\sum_{i=1}^{n} \sum_{i<j} x_i x_j Cov_{ij}} \tag{13}$$

Here $\sigma_p,$ represents the risk of portfolio, $\sigma_{i,}$ represents the variance of the returns of the i'th stock, and $Cov_{ij,}$ represents the covariance between i and j'th stocks.

Alpha Coefficient: It is a coefficient that measures the non-systematic risk of the price movement of securities and shows the return relative to the risk. If it is less than zero, it indicates that the expectation was smaller relative to the risk taken; if it is equal to zero, it indicates that the return is equal to the expectation relative to the risk; if it is larger than zero, it indicates that the return is higher than expectation relative to the risk taken.

The alpha coefficient, which is essentially regarded as a criterion of non-systematic risk, has an important place in modern portfolio theory due to its ability to be maintained by diversification. Because, in the portfolio selection, the Alpha coefficient is a measure of the contribution of the selection to the portfolio and has a linear correlation with the portfolio performance and is considered as an indicator of portfolio performance (Reilly & Brown, 2012).

Beta Coefficient: The beta coefficient is used to compare the market risk and stock certificate risk, and is a measure of volatility and systematic risk. The beta coefficient, which represents the slope of the regression line, is the ratio of the covariance of market return and stock return to the variation of market return and is calculated by the equation (14) (Ross et al., 2005).

$$\beta = COV\left(R_p R_i\right) / VAR\left(R_p\right) \tag{14}$$

$$R_p \; is \; market \; return \; and \; R_i \; is \; Stock \;\; Return$$

Sharpe Ratio: It assumes that there is a linear relationship between all securities and the market in which they are traded. Thus, the relationship between security and market is represented as a simple linear regression line. This performance criteria, claimed by William Sharpe who considered portfolio risk, has a simple applicability and is widely used in performance evaluation. The Sharpe Ratio, which is one of the risk-adjusted performance measurement techniques, is the ratio of the risk premium defined as the difference between the expected value of the portfolio and the risk-free interest rate to the standard deviation of the portfolio, and is calculated based on equation (15) (Sharpe, 1966).

$$\mathrm{SI} = \frac{r_m - r_f}{\sigma_p} \tag{15}$$

$$r_p : Expected \; return \; of \; portfolio$$

$$r_f : Risk \; Free \; Ratio$$

$$\sigma_p : Standard \; deviation \; of \; portfolio$$

Portfolios, components and portfolio risk, return and performance calculation results based on Fuzzy TOPSIS method are presented in Table 13-17.

Table 13. Portfolio components and results created by fuzzy TOPSIS 1

PORTFOLIO COMPONENTS					PORTFOLIO							
Stock Code	Weight (%)	Return	Risk	Beta	Return (%)	Risk (%)	Beta	Alfa (%)	R^2 (%)	Sharpe Ratio	Market Risk	Non-systematic Risk
AKSA	42.1529	0.1076	20.521	0.7672	0.1191	17.327	0.7943	0.0830	44.8358	0.0545	11.602	12.869
FROTO	57.8471	0.1275	21.405	0.8140								

In the study performed towards the applicability of Fuzzy TOPSIS method in selecting the optimal portfolio, the data of the bipartite portfolio formed according to Fuzzy TOPSIS for a comparison along the perspective of risk, performance and return according to the modern portfolio theory by Markowitz, which is widely accepted in finance literature, are presented in Table 13. The portfolio, which had a return of 0.1191%, had a risk of 1.7327%, its Beta value was 0.7943 and Alpha value was 0.0830%. Although the calculated values are theoretically acceptable, but for the requirement of proving its applicability in the literature, it would be more appropriate to compare them with the results of the portfolio component of Table 19, which is determined according to Markowitz's and gives the portfolio component at the same risk level. After the calculations to be performed based on Markowitz, the comparisons are made under the title Portfolio Evaluation and Comparison.

Table 14. Portfolio components and results created by fuzzy TOPSIS 2

PORTFOLIO COMPONENTS					PORTFOLIO							
Stock Code	Weight (%)	Return	Risk	Beta	Return (%)	Risk (%)	Beta	Alpha (%)	R^2 (%)	Sharpe Ratio	Market Risk	Non-systematic Risk
AKSA	29.9502	0.1076	20.521	0.7672	0.1186	15.807	0.7869	0.0827	52.8840	0.0595	11.495	10.850
FROTO	41.1011	0.1275	21.405	0.8140								
TAVHL	28.9486	0.1174	22.104	0.7689								

Table 14 presents the risk, return and performance indicator data for the portfolio and the component of the tripartite portfolio calculated based on Fuzzy TOPSIS. According to the indicator data of portfolio components generated, portfolio return is 0.1186% and its risk is calculated as 1.5807%. Its values in terms of performance are a Sharpe ratio of 0.0595 and an Alpha value of 0.0827%, and acceptable. However, for the applicability of the method in selecting the optimal portfolio, comparison with Markowitz's portfolio components is an iterable requirement.

Table 15. Portfolio components and results created by fuzzy TOPSIS 3

PORTFOLIO COMPONENTS					PORTFOLIO							
Stock Code	Weight (%)	Return	Risk	Beta	Return (%)	Risk (%)	Beta	Alpha (%)	R^2 (%)	Sharpe Ratio	Market Risk	Non-systematic Risk
AKSA	23.5010	0.1076	20.521	0.7672	0.1126	15.429	0.8256	0.0760	61.0887	0.0570	12.059	0.9625
ARCLK	21.5330	0.0905	21.765	0.9664								
FROTO	32.2508	0.1275	21.405	0.8140								
TAVHL	22.7151	0.1174	22.104	0.7689								

In Table 15, data of the four component portfolio formed based on Fuzzy TOPSIS are presented. The portfolio formed has a return level of 0.1126% and its risk is 1.5429%. In terms of performance criteria, the resulting 0.0570 Sharpe Ratio indicates a good efficiency.

Table 16. Portfolio components and results created by fuzzy TOPSIS 4

PORTFOLIO COMPONENTS					PORTFOLIO							
Stock Code	Weight (%)	Return	Risk	Beta	Return (%)	Risk (%)	Beta	Alpha (%)	R^2 (%)	Sharpe Ratio	Market Risk	Non-systematic Risk
AKSA	20.3205	0.1076	20.521	0.7672	0.1073	14.943	0.8349	0.0706	66.6053	0.0553	12.196	0.8635
ARCLK	18.6189	0.0905	21.765	0.9664								
FROTO	27.8862	0.1275	21.405	0.8140								
TAVHL	19.6410	0.1174	22.104	0.7689								
TUPRS	13.5334	0.0733	20.067	0.8944								

In Table 16, components of the portfolio of 5 stocks and the performance, risk and return outcomes of the portfolio are presented. The risk of the portfolio, which has 0.1073% income, is 1.4943%. In terms of performance values, with Sharpe Ratio of 0.0553 and Alpha value of 0.0706%, it gave positive results.

Table 17. Portfolio components and results created by fuzzy TOPSIS 5

PORTFOLIO COMPONENTS					PORTFOLIO							
Stock Code	Weight (%)	Return	Risk	Beta	Return (%)	Risk (%)	Beta	Alpha (%)	R^2 (%)	Sharpe Ratio	Market Risk	Non-systematic Risk
AKSA	18.3545	0.1076	20.521	0.7672	0.1034	14.397	0.8187	0.0669	69.0139	0.0547	11.960	0.8014
ARCLK	16.8174	0.0905	21.765	0.9664								
FROTO	25.1881	0.1275	21.405	0.8140								
TAVHL	17.7407	0.1174	22.104	0.7689								
TTKOM	9.6753	0.0669	17.595	0.6681								
TUPRS	12.2240	0.0733	20.067	0.8944								

In Table 17, portfolio data based on 6 stocks formed according to the Fuzzy TOPSIS are presented. The risk of the portfolio, which has 0.1034% income, is 1.4397%. Portfolio outcomes, which reveal efficient results in terms of performance values, suggest the method's applicability in the selection of optimal portfolio. Besides all these explanations, as can be seen in the portfolio components determined based on Markowitz Model, diversification effect is in parallel with its negative correlation with return and risk.

3.2.2 Evaluation and Comparison of Portfolios

Evaluations on different portfolio alternatives formed via Fuzzy TOPSIS Method will be done through comparing with the portfolios formed based on modern portfolio theory. However, first, mutual interaction between the stock certificates and the level of this interaction is shown by preparing the covariance matrix of the stock certificates that are essential to the diversification composed of stock recommendations. Covariance matrix for the relevant stocks is shown in Table 18.

Table 18. Covariance matrix of stocks

XUTUM	AEFES	AKSA	ARCLK	BANVT	ENKAI	EREGL	KOZAL	FROTO	MGROS	PETKM	SELEC	TAVHL	TKFEN	TTKOM	TUPRS
AEFES	40.214	0.8859	11.648	0.9424	0.9643	0.7273	0.9666	0.8380	10.519	0.8724	0.7998	0.8825	0.9450	0.8584	10.310
AKSA	0.8859	42.111	16.768	15.262	13.634	15.044	14.781	10.372	18.337	15.172	13.493	13.584	17.572	11.365	14.281
ARCLK	11.648	16.768	47.373	17.263	16.749	17.220	19.913	11.613	17.913	15.947	12.431	18.026	20.085	14.860	18.658
BANVT	0.9424	15.262	17.263	49.565	11.952	15.440	16.152	13.255	19.167	15.123	12.913	15.039	16.688	10.753	14.045
ENKAI	0.9643	13.634	16.749	11.952	37.059	13.956	13.838	12.433	15.195	13.850	11.109	14.620	17.120	10.265	14.347
EREGL	0.7273	15.044	17.220	15.440	13.956	34.496	13.778	13.805	17.449	16.620	12.118	15.885	16.291	10.795	15.205
FROTO	0.9666	14.781	19.913	16.152	13.838	13.778	45.819	11.343	21.562	13.623	11.730	14.197	18.428	12.273	17.227
KOZAL	0.8380	10.372	11.613	13.255	12.433	13.805	11.343	68.717	14.347	11.119	10.596	12.165	11.780	10.512	14.072
MGROS	10.519	18.337	17.913	19.167	15.195	17.449	21.562	14.347	57.911	19.393	15.146	16.616	21.852	14.764	17.920
PETKM	0.8724	15.172	15.947	15.123	13.850	16.620	13.623	11.119	19.393	37.439	11.881	13.713	18.795	11.023	15.502
SELEC	0.7998	13.493	12.431	12.913	11.109	12.118	11.730	10.596	15.146	11.881	35.202	10.163	15.279	0.7856	12.696
TAVHL	0.8825	13.584	18.026	15.039	14.620	15.885	14.197	12.165	16.616	13.713	10.163	48.857	18.467	11.133	14.447
TKFEN	0.9450	17.572	20.085	16.688	17.120	16.291	18.428	11.780	21.852	18.795	15.279	18.467	42.729	14.710	19.164
TTKOM	0.8584	11.365	14.860	10.753	10.265	10.795	12.273	10.512	14.764	11.023	0.7856	11.133	14.710	30.957	14.812
TUPRS	10.310	14.281	18.658	14.045	14.347	15.205	17.227	14.072	17.920	15.502	12.696	14.447	19.164	14.812	40.268

In Modern Portfolio Theory, investor's asset combinations with the lowest risk at different return levels are called effective portfolio. Each portfolio component above the active border shows either the components that provide risk minimization at a certain return level or provide return maximization at a certain risk level. In order to be able to comparatively evaluate the portfolio components formed based on the fuzzy TOPSIS method in terms of risk, return and performance trilogy, effective portfolio components with the same rate of return should be taken as basis. The active border curve that the efficient portfolio components of the stock shares formed according to the brokerage house's recommendations is based on is presented in Figure 3.

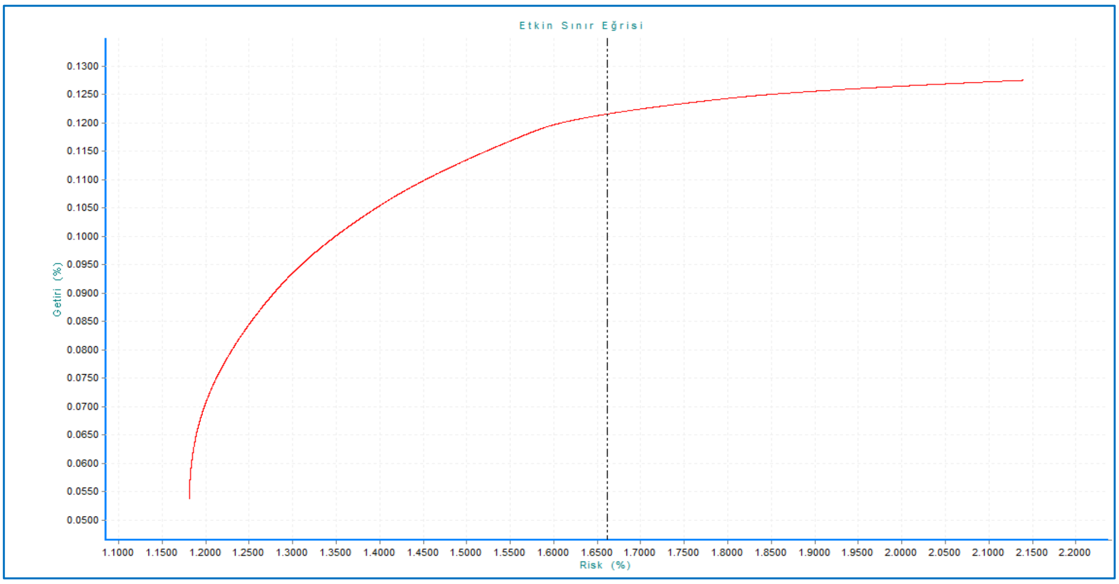

Figure 3. Effective boundary curve

Markowitz efficient portfolio components that show the target return level in portfolio components calculated based on Fuzzy TOPSIS Method and the risk, return, and performance calculations of these portfolio are calculated based on the formulae of equations 15-18 and are shown in Table 19-23.

Table 19. Portfolio components and results created by markowitz 1

PORTFOLIO COMPONENTS	
Stock Code	Weights (%)
FROTO	42.5375
TAVHL	30.8100
AKSA	26.6526

PORTFOLIO							
Return %	Risk %	Beta	Alpha%	R^2%	Sharpe Ratio	Market Risk	Non-systematic Risk
0.1073	14.943	0.8349	0.0706	66.6053	0.5553	12.196	0.8635

The results of the portfolio component shown in Table 12 among the portfolio components determined by the Fuzzy TOPSIS Method are acceptable in terms of risk, return, performance and other results. However, the same target return in terms of the relevant portfolio can be achieved via the efficient portfolio component in Table 19 based on the Markowitz model. When both portfolio components are compared, it can be seen that the portfolio component based on Markowitz model is more advantageous in terms of risk. However, in terms of Alpha coefficient, the return based on the risk taken seems satisfactory. In terms of market risk, the outlook that seems in favor of the Markowitz model can be interpreted as the effect of diversification based on the surplus of portfolio components.

Table 20. Portfolio components and results created by markowitz 2

PORTFOLIO COMPONENTS	
Stock Code	Weights (%)
FROTO	40.9968
TAVHL	30.5623
AKSA	27.7723
EREGL	0.6686

PORTFOLIO							
Return %	Risk %	Beta	Alpha%	R^2%	Market Risk	Sharpe Ratio	Non-systematic Risk
0.1186	1.5792	0.7871	0.0879	53.0117	1.1498	0.0751	1.0825

The results of the portfolio component shown in Table 12 among the portfolio components determined by the

Fuzzy TOPSIS method are acceptable in terms of risk, return, performance and other results. However, the same target return in terms of the relevant portfolio can be achieved via the efficient portfolio component in Table 20 based on the Markowitz model. When both portfolio components are compared, the similarity between the portfolio components and the similarity between these components in terms of their significance in the portfolio are striking. Although the diversification intensity is higher in Markowitz model, the portfolio components composed of the same stock certificates reveals that the Fuzzy TOPSIS method is more applicable. However, it can be said that the portfolio results are in favor of Markowitz model.

Table 21. Portfolio components and results created by markowitz 3

PORTFOLIO COMPONENTS	
Stock Code	Weights (%)
FROTO	34.8357
TAVHL	26.5067
AKSA	24.8737
TTKOM	5.5295
EREGL	4.9523
PETKM	3.3021

PORTFOLIO							
Return %	Risk %	Beta	Alpha%	R^2%	Market Risk	Sharpe Ratio	Non-systematic Risk
0.1126	1.4874	0.7818	0.0821	58.9513	1.1420	0.0757	0.9530

Among the portfolio components determined according to the Fuzzy TOPSIS Method, the results of the portfolio component in Table 12 seem acceptable in terms of risk, return, performance and other results. According to Markowitz model, the same target return can be achieved via the efficient portfolio component in Table 21. When both portfolio components are compared; high explanatory power of the determination coefficient of the fuzzy TOPSIS portfolio component is striking. Although it points to an evaluation in favor of the method, the low portfolio risk based on the intensity of diversification in the Markowitz model portfolio component may be considered sufficient since the aim of the study is to reveal that the fuzzy TOPSIS method can be used rather than to compare the methods.

Table 22. Portfolio components and results created by markowitz 4

PORTFOLIO COMPONENTS	
Stock Code	Weights (%)
FROTO	29.6054
TAVHL	23.0246
AKSA	22.1936
TTKOM	11.2673
EREGL	7.7738
PETKM	6.1353

PORTFOLIO							
Return %	Risk %	Beta	Alpha%	R^2%	Market Risk	Sharpe Ratio	Non-systematic Risk
0.1073	1.4202	0.7760	0.0770	63.6934	1.1335	0.0755	0.8558

According to Fuzzy TOPSIS Method, the results of the portfolio component shown in Table 12 are acceptable in terms of risk, return, performance and other results. The target return level of 0.1073% can be achieved in Markowitz model via the efficient portfolio component in Table 22. While lower risk level of the Markowitz model based on diversification is observed in the comparison, higher explanatory power in terms of determination coefficient is in favor of fuzzy TOPSIS method portfolio component.

Table 23. Portfolio components and results created by markowitz 5

PORTFOLIO COMPONENTS	
Stock Code	Weights (%)
FROTO	26.3965
TAVHL	20.8580
AKSA	20.4593
TTKOM	14.1244
EREGL	9.2394
PETKM	7.5170
AEFES	1.4053

PORTFOLIO							
Return %	Risk %	Beta	Alpha%	R^2%	Market Risk	Sharpe Ratio	Non-systematic Risk
0.1034	1.3799	0.7690	0.0733	66.2732	1.1234	0.0749	0.8014

Among the portfolio components determined based on the Fuzzy TOPSIS method, the return level in the portfolio component shown in Table 12 can be achieved through the efficient portfolio shown in Table 23 based on the Markowitz Model. Fuzzy TOPSIS portfolio component is acceptable in terms of its risk, return, performance and other results, and has a higher explanatory power than Markowitz in terms of determination coefficient. Diversification intensity is more intense in Markowitz portfolio component, and because of that, it carries a relatively lower risk. However, it is in favor of Fuzzy TOPSIS method, which has a higher determination coefficient in terms of the power to obtain the target return.

4. Overall Evaluation and Conclusion

As a result of the findings of this study which investigates the applicability of Fuzzy TOPSIS Method as an alternative method in optimal portfolio selection, it was found that portfolio components obtained according to the method are applicable based on their risk, return, performance and other results. Since the relatively lower risk at the same return level provided by the active portfolios determined according to Markowitz's Modern Portfolio Theory emphasizes the superiority of the method, its goal is not to compare the methods when deciding the optimal portfolio selection, and thus, the applicability of fuzzy TOPSIS method will not be altered. However, since fuzzy TOPSIS method is based on the linguistic evaluation of the decision makers, it is open for improvement based on the accumulation of knowledge of the decision makers about the decision criteria. It can also be said that the method requires improvement. This deficiency in the fuzzy TOPSIS method can be seen more clearly when the effect of the diversification in the portfolio components and the relatively lower risk in the Markowitz method are taken into account. However, it can be said that, in all the portfolio components calculated according to the method, higher explanatory power obtained by the magnitude of the determination coefficient and with the improvement devised towards diversification, more positive results that can be achieved.

References

Aksoy, A., & Tanrıoven, C. (2007). *Sermaye Piyasası Yatırım Araçları ve Analizi, 3.Baski*. Ankara: Gazi Kitabevi.

Akyuz, G., & Kilinc, E. (2016). Using Fuzzy TOPSIS Approach for Facility Location Selection: An Application in Medical Sector. *Journal of Academic Social Science, 4*(33), 590-608.

Alemi, M. A., & Akram, R. (2013). Measuring the Leanness of Manufacturing Systems by Using Fuzzy TOPSIS: A Case Study of the 'Parızan Sanat' Company. *South African Journal of Industrial Engineering, 24*(3), 166-174.

Altas, I. H. (1999). Bulanık Mantık: Bulanıklık Kavramı. *Enerji, Elektrik, Elektromekanik-3e, 62,* 80-85.

Ardakani, S. S., Nejatian, M., Farhangnejad, M. A., & Nejati, M. (2015). A Fuzzy Approach to Service Quality Diagnosis. *Marketing Intelligence& Planning, 33*(1), 103-119. http://dx.doi.org/10.1108/MIP-02-2013-0035

Arslan, H. M., & Yildiz, M. S. (2015). Application of Fuzzy TOPSIS Method on Location Selection of Educational Facilities: A Location Analysis in Duzce. *The Journal of International Social Research, 8*(36), 763-773. https://doi.org/10.17719/jisr.2015369541

Ashrafzadeh, M., Rafiei, F. K., Isfahani, N. M., & Zare, Z. (2012). Application of Fuzzy TOPSIS Method for the Selection of Warehouse Location: A Case Study. *Interdisciplinary Journal of Contemporary Research in Business, 3*(9), 655-671.

Awasthi, A., & Chauhan, S. S. (2012). A Hybrid Approach Integrating Affinity Diagram, AHP and Fuzzy TOPSIS for Sustainable City Logistics Planning. *Applied Mathematical Modelling*, *36*(2), 573-584. https://doi.org/10.1016/j.apm.2011.07.033

Bagheri, F., & Tarokh, M. J. (2010). A Fuzzy Approach for Multi-Objective Supplier Selection. *International Journal of Industrial Engineering & Production Research, 21*(1), 1-9.

Baskaya, Z., & Ozturk, B. (2011). Evaluation of Salesperson Candidate's with Fuzzy TOPSIS. *Business and Economics Research Journal, 2*(2), 77-100.

Bottani, E., & Rizzi A. (2006). A fuzzy TOPSIS Methodology to Support Outsourcing of Logistics Services. *Supply Chain Management: An International Journal, 11*(4), 294-308. https://doi.org/10.1108/13598540610671743

Buyukozkan, G., & Cifci, G. (2012). A Novel Hybrid MCDM Approach Based on Fuzzy DEMATEL, Fuzzy ANP and Fuzzy TOPSIS to Evaluate Green Suppliers. *Expert Systems with Applications, 39*(3), 3000-3011. https://doi.org/10.1016/j.eswa.2011.08.162

Ceylan, A., & Korkmaz, T. (1998). *Borsada Uygulamalı Portföy Yönetimi*. Bursa: Ekin Yayınları.

Chen, C. T. (2000). Extensions of the TOPSIS for Group Decision-Making under Fuzzy Environment. *Fuzzy Sets and Systems, 114*(1), 1-9. https://doi.org/10.1016/S0165-0114(97)00377-1

Chen, C. T. (2001). A Fuzzy Approach to Select The Location of The Distribution Center. *Fuzzy Sets and Systems, 118*(1), 65-73. https://doi.org/10.1016/S0165-0114(98)00459-X

Chen, C. T., Lin, C. T., & Huang, S. F. (2006). A fuzzy approach for supplier evaluation and selection in supply chain management. *Int. J. Production Economics, 102*(2), 289-301. https://doi.org/10.1016/j.ijpe.2005.03.009

Chen, S. J., & Hwang, C. L. (1992). *Fuzzy Multiple Attribute Decisin Making Methods and Applicatons.* Berlin Heidelberg: Springer-Verlag. https://doi.org/10.1007/978-3-642-46768-4

Chen, S. Y., & Lu, C. C. (2015). Assessing the competitiveness of insurance corporations using fuzzy correlation analysis and improved fuzzy modified TOPSIS. *Expert Systems, 32*(3), 392-404. https://doi.org/10.1111/exsy.12099

Deng, H., Yeh, C. H., & Willis, R. J. (2000). Inter-Company Comparison using Modified TOPSIS with Objective Weights. *Computers & Operations Research, 27*(10), 963-973. https://doi.org/10.1016/S0305-0548(99)00069-6

Dundar, S., Ecer, F., & Ozdemir, S. (2007). Fuzzy TOPSIS Yöntemi İle Sanal Mağazaların Web Sitelerinin Değerlendirilmesi. *Ataturk University Journal of Economics and Administrative Sciences, 21*(1), 287-305.

Ecer, F. (2006). Bulanık Ortamlarda Grup Kararı Vermeye Yardımcı Bir Yöntem: Fuzzy TOPSIS ve Bir Uygulama. *Istanbul University Journal of The School of Business, 7*(2), 77-96.

Ecer, F. (2007). A New Approach Towards Evaulation and Selection of Salesperson Candidates: Fuzzy TOPSIS. *Anadolu University Journal of Social Sciences, 7*(2), 187-204.

Ecer, F. (2007). Evaluation of Store Plant Locations in Fuzzy Environments: Fuzzy TOPSIS Method as a Decision-Making Tool. *Hacettepe University the Journal of Faculty of Economics and Administrative Sciences, 25*(1), 143-170.

Ecer, F., Vurur, N. S., & Ozdemir, L. (2009). Assessing of Firms Using A Fuzzy Model and Optimal Portfolio Composing: An Application In Cement Industry. *Mustafa Kemal University Journal of Social Sciences Institute, 6*(11), 478-502.

Eleren, A., & Ersoy, M. (2007). Evaluation of Marble Extraction Methods By Using Fuzzy TOPSIS Method. *The Journal of the Chamber of Mining Engineers of Turkey, 46*(3), 9-22.

Eleren, A., & Yilmaz, C. (2011). Selection of Suppliers by Fuzzy TOPSIS Model; Sample Study From Turkey. *International Journal of Business and Social Science, 2*(22), 189-200.

Eraslan, E., & Tansel, Y. (2011). A Multi-criteria Approach for Determination of Investment Regions: Turkish case. *Industrial Management & Data Systems, 111*(6), 890-909. https://doi.org/10.1108/02635571111144964

Erginel, N., Cakmak, T., & Senturk, S. (2010). Determining The Preference of GSM Operators In Turkey with Fuzzy TOPSIS After Mobile Number Portability System Application. *Anadolu University Journal of*

Science and Technology–A Applied Sciences and Engineering, 11(2), 81-93.

Erkayman, B., Gundogar, E., Akkaya, G., & Ipek, M. (2011). A Fuzzy TOPSIS Approach For Logistics Center Location Selection. *Journal of Business Case Studies*, *7*(3), 49-55. https://doi.org/10.19030/jbcs.v7i3.4263

Gokdalay, M. H., & Evren, G. (2009). Fuzzy multicriteria decision making approach for airport performance analysis. *Itüdergisi/d Mühendislik, 8*(6), 157-168.

Gul, D., & Uludag, A. S. (2016). Determination of the Most Charismatic Leader Using Analytic Hierarchy Process and Fuzzy TOPSIS: An Application in Turkey. *International Business Research*, *9*(7), 80-97. https://doi.org/10.5539/ibr.v9n7p80

Hsu, L.C., Ou, S. L., & Ou, Y. C. (2015). A Comprehensive Performance Evaluation and Ranking Methodology Under A Sustainable Development Perspective. *Journal of Business Economics and Management, 16*(1), 74-92. https://doi.org/10.3846/16111699.2013.848228

Huang, J. H., & Peng, K. H. (2012). Fuzzy Rasch Model in TOPSIS: A New Approach for Generating Fuzzy Numbers to Assess the Competitiveness of the Tourism Industries in Asian Countries. *Tourism Management*, *33*(2), 456-465. https://doi.org/10.1016/j.tourman.2011.05.006

Kabra, G., & Ramesh, A. (2015). Analyzing Drivers and Barriers of Coordination in Humanitarian Supply Chain Management under Fuzzy environment. *Benchmarking: An International Journal*, *22*(4), 559-587. https://doi.org/10.1108/BIJ-05-2014-0041

Kahraman, C., Ates, N.Y., Cevik, S., Gulbay, M., & Erdogan, S. A. (2007). Hierarchical Fuzzy TOPSIS Model for Selection among Logistics Information Technologies. *Journal of Enterprise Information Management, 20*(2), 143-168. https://doi.org/10.1108/17410390710725742

Kahraman, C., Suder, A., & Cebi, S. (2013). Fuzzy Multi-criteria and Multi-experts Evaluation of Government Investments in Higher Education: the Case of Turkey. *Technological and Economic Development of Economy*, *19*(4), 549-569. https://doi.org/10.3846/20294913.2013.837110

Karan, M. B. (2011). *Yatırım Analizi ve Portföy Yönetimi, 3.Baski*. Ankara: Gazi Kitabevi.

Kocel, T. (2005). *İsletme Yonetimi, 10.Baskı*. Istanbul: Arikan.

Konuralp, G. (2005). *Sermaye Piyasaları&Analizler Kuramlar ve Portföy Yönetimi, 2.Baski*. Istanbul: Alfa.

Kucuk, O., & Ecer, F. (2007). Assesing Suppliers Using Fuzzy TOPSIS and An Applıcation in Erzurum. *The International Journal of Economic and Social Research, 3*(1-3), 45-65.

Madi, E. N., & Tap, A. O. M. (2011). Fuzzy TOPSIS Method in the Selection of Investment Boards by Incorporating Operational. *Proceedings of the World Congress on Engineering 2011*, July 6-8, Vol I.

Mahdevari, S., Shahriar, K., & Esfahanipour. (2014). Human health and safety risks management in under ground coalmines using fuzzy TOPSIS. *Science of the Total Environment*, *488-489*, 85-99. https://doi.org/10.1016/j.scitotenv.2014.04.076

Mahdi, B., & Hossein, B. (2008). Project Selection with Outsourcing View Using Fuzzy TOPSIS Linear Assignment Programming. *Proceedings of the 2008 IEEE*, 327-332. https://doi.org/10.1109/ICMIT.2008.4654385

Maity, S. R., & Chakraborty, S. (2013). Grinding Wheel Abrasive Material Selection Using Fuzzy TOPSIS Method. *Materials and Manufacturing Processes*, *28*(4), 408-417. https://doi.org/10.1080/10426914.2012.700159

Mangır, F., & Erdogan, S. (2011). Comparison of Economic Performance Among Six Countries in Global Financial Crisis: The Application of Fuzzy TOPSIS Method. *Economics, Management, and Financial Markets, 6*(2), 122-136.

Mokhtari, S. M., Alinejad-Rokny, H., & Jalalifar, H. (2014). Selection of the best well control system bey using fuzzy multiple-attribute decision-making methods. *Journal of Applied Statistics*, *41*(5), 1105-1121. https://doi.org/10.1080/02664763.2013.862218

Onut, S., & Soner, S. (2008). Transshipment site selection using the AHP and TOPSIS approaches under fuzzy environment. *Waste Management*, *28*, 1552-1559. https://doi.org/10.1016/j.wasman.2007.05.019

Ozcakar, N., & Demir, H. (2011). Supplier Selection by Using The Fuzzy TOPSIS Method. *Yönetim: İstanbul Üniversitesi İşletme İktisadi Enstitüsü Dergisi, 22*(69), 25-44.

Ozdemir, A. I., & Secme, N. Y. (2009). İki Asamalı Stratejik Tedarikci Seciminin Bulanık TOPSIS Yontemi Ile Analizi. *Afyon Kocatepe Univesity Journal of Economics and Administrative Sciences, 11*(2), 79-112.

Ozturk, A., Ertugrul, I., & Karakasoglu, N. (2008). Comparison of Fuzzy AHP and Fuzzy TOPSIS Methods in Transportation Firm Selection. *Marmara University Journal of Economics and Administrative Sciences, 25*(2), 785-824.

Paksoy, T., Pehlivan, N. Y., & Kahraman, C. (2012). Organizational Strategy Development in Distribution Channel Management using Fuzzy AHP and Hierarchical Fuzzy TOPSIS. *Expert Systems with Applications, 39*(3), 2822-2841. https://doi.org/10.1016/j.eswa.2011.08.142

Prascevic, Z., & Prascevic, N. (2013). One modification of Fuzzy TOPSIS method. *Journal of Modelling in Management, 8*(1), 81-102. https://doi.org/10.1108/17465661311311996

Reilly, F. K., & Brovn, K. C. (2012). *Investment Analysis&Portfolio Management* (10th ed.). South-Western Cengage Learning, Ö ice Presidend of Editorial Business, Boulevard, USA.

Ross, W. J. (2005). *Corporate Finance* **(**Vol. 1, 6th ed.). McGraw-Hill/Irwin, HcGravw-Hill Primis.

Salehi, M., & Tavakkoli-Moghaddam, R. (2008). Project Selection by Using a Fuzzy TOPSIS Technique. *International Scholarly and Scientific Research & Innovation, 2*(4), 375-380.

Sari, K. (2013). Selection of RFID Solutionprovider. *Kybernetes, 42*(3), 448-465. https://doi.org/10.1108/03684921311323680

Sedaghat, M. (2013). A Productivity Improvement Evaluation Model By Integrating AHP, TOPSIS and VIKOR Methods Under Fuzzy Environment (Case Study: Stateowned, Partially Private and Private Banks in Iran). *Economic Computation & Economic Cybernetics Studies & Research, 47*(1), 235-258.

Shahanaghi, K., & Yazdian, S. A. (2009). Vendor Selection Using a New Fuzzy Group TOPSIS Approach. *Journal of Uncertain Systems, 3*(3), 221-231.

Sharpe, W. F. (1966). "Mutual Fund Performance", *The Journal of Business, 39*(1), 119-138 https://doi.org/10.1086/294846

Solimanpur, M., Mansourfar, G., & Ghayour, F. (2015). Optimum Portfolio Selection Using a Hybrid Genetic Algorithm and Analytic Hierarchy Process. *Studies in Economics and Finance, 32*(3), 379-394. https://doi.org/10.1108/SEF-08-2012-0085

Sun, C. C., & Lin, G. T. R. (2009). Using fuzzy TOPSIS Method for Evaluating the Competitive Advantages of Shopping websites. *Expert Systems with Applications, 36,* 11764-11771. https://doi.org/10.1016/j.eswa.2009.04.017

Tan, Y., Shen, L., Langston, C., & Liu, Y. (2010). Construction Project Selection Using Fuzzy TOPSIS Approach. *Journal of Modelling in Management, 5*(3), 302-315. https://doi.org/10.1108/17465661011092669

Tirmikcioglu, C. N. (2010). Fuzzy TOPSIS Method for Facility Location Selection and An Application in Banking Sector. *Karamanoglu Mehmet Bey University Journal of Social and Economic Research, 12*(18), 37-45.

Tsao, C. T. (2003). Evaluating Investment Values of Stocks Using A Fuzzy TOPSIS Approach. *Journal of Information and Optimization Sciences, 24*(2), 373-396. https://doi.org/10.1080/02522667.2003.10699573

Ulgen, H., & Mirze, S. K. (2010). *İşletmelerde Stratejik Yönetim.* İstanbul: Beta Basım Yayın.

Uludag, A. S., & Deveci, M. (2013b). Using The Multi Criteria Decision Making Methods in Facility Location Selection Problems and An Application. *Abant Izzet Baysal University Journal of Social Sciences, 13*(1), 257-288.

Uludag, A. S., Deveci, M. (2013a). Supplier Selection using the Fuzzy VIKOR and Fuzzy TOPSIS Methods and an Application. *European Journal of Scientific Research, 98*(2), 240-258.

Uysal, F., & Tosun, O. (2012). Fuzzy TOPSIS-Based Computerized Maintenance Management System Selection. *Journal of Manufacturing Technology Management, 23*(2), 212-228. https://doi.org/10.1108/17410381211202205

Vatansdever, K. (2013). Use of Fuzzy TOPSIS Method in Supplier Selection Decision and an Application. *Anadolu University Journal of Social Sciences, 13*(3), 155-168.

Vural, M. (2002). DüşünceTarihinde Mantık: Aristoteles Mantığından Bulanık Mantığa. *Kutadgubilig, 2,* 179-192.

Website: http://www.tdkterim.gov.tr/bts/

Yayla, A. Y., Yildiz, A., & Ozbek, A. (2012). Fuzzy TOPSIS Method in Supplier Selection and application in the Garment Industry. *FIBRES & TEXTILES in Eastern Europe, 4*(93), 20-23.

Yildiz, A., & Yildiz, D. (2014). Enterprice Resource Planning (ERP) Software Selection Process with Fuzzy TOPSIS Method. *Business and Economics Research Journal*, *5*(1), 87-106.

Yong, D. (2006). Plant location selection based on fuzzy TOPSIS. *Int.J.Adv.MAnuf.Technol.*, *28*, 839-844. https://doi.org/10.1007/s00170-004-2436-5

Yoruk, N. (2000). *Finansal Varlık Fiyatlama Modelleri ve Arbitraj Fiyatlama Modelinin İMKB'de Test Edilmesi.* Istanbul: Istanbul Menkul Kıymetler Borsası.