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Borsa İstanbul'da İşlem Gören Gayrimenkul Şirketlerinin Nötrosofik AHP ve TOPSIS Yöntemiyle Performanslarının Sıralanması

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Öne Çıkanlar:
- Borsada hisse senedi seçimi
- alternatifleri sıralama
- karar verme

Anahtar Kelimeler:
- Belirsizlik,
- çok kriterli karar verme
- nötrosofik AHP
- nötrosofik TOPSİS
- BİST

ÖZET:

Hayatta birçok alanda belirsizlikler vardır ve belirsizlikler altında karar verilmesi gerektiği zamanlarda insanlar matematiksel verilere ihtiyaç duymaktadır. Bu çalışmada, Borsa İstanbul (BİST)'da işlem gören gayrimenkul şirketlerin, geçmiş finansal performansları dikkate alınarak çok kriterli karar verme yöntemlerinden AHP ve TOPSIS yönteminin nötrosofik kümelere entegre edilmesi ve bütünleşik bir modelle, yatırım için uygunlukları değerlendirilmiştir. Bu çalışma, belirsizliğin çok fazla görüldüğü bir alanda karar vermek isteyen yatırımcıların risklerini en aza indirgemeleri ve verilebilecek optimum kararı vermelerinde matematiksel verilerden yararlanmalarını sağlamak amacıyla yapılmıştır. Bu kapsamda, nötrosofik kümelerin tanımı ve temel özellikleri, nötrosofik AHP ve TOPSIS bütünleşik modeli verilmiş bu modele göre BİST'e işlem gören gayrimenkul şirketlerinin geçmiş performansları ele alınarak şirketlerin yatırıma uygunlukları için bir sıralama yapılmıştır. Bu işlemler yapılırken borsa yatırım analistlerinden üç karar vericiden kriterlerin önem derecelerini ve şirketlerin bu kriterlere göre durumlarını sözel ifadelerle belirtmeleri sağlanmış bu sözel ifadeler nötrosofik skorlara dönüştürülmüştür. Nötrosofik AHP yöntemi ile kriterlerin önem ağırlıkları hesaplanmış nötrosofik TOPSIS yöntemiyle de şirketlerin kriterlere göre durumları hesaplanıp şirketlerin optimum yatırıma uygunlukları sıralanmıştır. Çalışmanın özgünlüğü; elde edilen bulguların diğer çalışmalardan farklı olarak belirsizlik durumlarının büyük oranda hesaba katılmasıyla riskleri en aza indirgemiş olmasıdır. Aynı zamanda karar vericilerin belirsizlik değeri için bir kısıtlama olmadan sözel ifade kullanabiliyor olmalarıdır. Dış faktörlerin borsa için çok önemli olduğu açıktır ve karar verici bunu göz önüne alarak belirsizlik oranını yüksek tutabilir. Buda belirsizliklerden doğacak riskleri en aza indirgemek için yeni bir yöntem sunmaktadır.

Ranking The Performance Of Real Estate Companies Listed On Borsa Istanbul Using Neutrosophic AHP And TOPSIS Methods

Highlights:
- The selection of stocks in the stock market
- listing the alternatives
- decision making

Keywords:
- Uncertainty
- multi-criteria decision making
- neutrosophic AHP
- neutrosophic TOPSIS
- BİST

ABSTRACT:

In many areas of life, uncertainties exist, and decisions under these uncertainties require mathematical data. This study evaluates the investment suitability of real estate companies listed on Borsa Istanbul (BIST) by integrating neutrosophic sets with AHP and TOPSIS methods. The aim is to help investors minimize risks and make optimal decisions in highly uncertain environments. The study defines neutrosophic sets and presents an integrated neutrosophic AHP and TOPSIS model. The past performance of BIST-listed real estate companies was analyzed for investment suitability. Three stock market analysts indicated the importance of various criteria and expressed company statuses using verbal terms, which were converted into neutrosophic scores. Criteria importance weights were calculated with neutrosophic AHP, and company statuses were evaluated with neutrosophic TOPSIS, resulting in a ranking of companies. The study's uniqueness lies in significantly accounting for uncertainty to minimize risks, allowing decision-makers to use unrestricted verbal expressions for uncertainty. This method considers external factors crucial to the stock market, offering a new approach to minimize risks from uncertainties.

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INTRODUCTION

Companies have various objectives, but one of the most important goals is to make a profit. Publicly traded companies listed on the Borsa Istanbul (BIST) also aim to make a profit. At the same time, individuals with fixed incomes need an investment instrument to evaluate their savings. One of these investment instruments is stocks in the Turkish stock market. In today's competitive markets, both companies and individual investors need to make the right decisions to make a profit. The aim of the stock market is also to have a small share in large companies, support their investments, and receive profits and dividends from their shares.

Throughout history, people have always faced decision-making situations. Decision-making can be defined as determining the best-described situation. If there is only one criterion in the decision-making process, the most suitable candidate/candidates can be easily selected. However, decision-making is difficult in multi-criteria situations. Like in any choice problem, the selection of an investment instrument is also a type of decision-making problem. Such decision-making problems pose significant risks to ensuring solution accuracy due to their inclusion of personal judgments and subjectivity. This leads decision-makers to systematic methods in problem-solving. Numerous literature studies have attempted to solve decision-making problems in many areas. Major application areas include personnel selection by human resources, economic choices, career-related decisions, and so on. Some studies have also been conducted in the field of decision-making under uncertainty using neutrosophic sets. The aim of this study is to rank companies based on their past financial performance among real estate companies listed on the stock exchange using two multi-criteria decision-making (MCDM) methods, Analytic Hierarchy Process (AHP), and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), which are widely applied in various fields in the literature. The selection of real estate companies is influenced by the advanced construction sector in our country and significant investments made by companies domestically and internationally. Neutrosophic set theory has been used to ensure more effective results in the solution of real-life problems involving uncertainty. With the neutrosophic AHP method, the most important criteria for pre-selected companies were determined, and the weights of these criteria were ranked. The weights of these ranked criteria were used in the neutrosophic TOPSIS method to determine and rank the performance of companies. It is more important to choose the appropriate solution tool than to solve a problem. Therefore, the frequent application of neutrosophic AHP and neutrosophic TOPSIS methods in the literature in different fields and the suitability of the solution steps to the existing problem structure have been effective in the selection of these methods. It was determined that these methods have been used in different stock selections in the past, but a study using neutrosophic sets has not been conducted. Unlike previously used sets, uncertainty has been included in the criteria here, and uncertainty has been addressed in the decisions to be made.

The stock market can be influenced by many different factors and has a highly complex structure. Growth data, inflation rates, unemployment rates, political instability, wars, natural disasters, company performance, and profitability can deeply affect stock markets. Particularly, geopolitical tensions related to energy resources and developments in international markets can increase uncertainties in the stock market. The significant impact of these uncertainties on stock markets makes the purpose of this study highly important.

Lıterature Revıew

A literature review was conducted on studies utilizing decision-making methods involving neutrosophic sets and decision-making methods related to the stock market.

According to Karataş (2019), the selection of personnel by companies is also a decision-making problem. It is anticipated that personnel selection, due to its inclusion of personal judgments and subjectivity, may lead to serious risks in outcomes. Therefore, for the personnel selection process, AHP and TOPSIS methods from multi-criteria decision-making (MCDM) methods were used, and at the same time, the aim was to solve the problem using interval-valued neutrosophic sets to achieve more effective handling of uncertain situations.

According to Boltürk (2019), decision-making methods were employed in the selection of renewable energy using interval-valued neutrosophic AHP and cosine similarity method, and the results were compared after two applications. In the application, both cost and benefit criteria were utilized.

According to Özcan (2020), one of the most important problems for logistics companies is selecting a warehouse location. In order to make this selection, some alternatives from Arab Gulf countries were identified, and the most suitable warehouse location was chosen using the Interval Valued Neutrosophic method, a multi-criteria decision-making (MCDM) method.

According to Erdem (2021), in the telecommunications sector, analyses of the criteria causing customer churn were conducted using an integrated model of single-valued neutrosophic sets and multi-criteria decision-making (MCDM) methods. Criteria were evaluated, and the most important criterion was identified in this assessment, determining it to be the most significant factor contributing to customer churn.

According to Kurtul (2021), the ratio analysis method was used for performance measurement on manufacturing sector companies listed on the Borsa Istanbul (BIST), while multi-criteria decision-making (MCDM) methods were employed for comparison and evaluation. The aim was to determine the best alternative using MCDM methods and to rank the alternatives.

According to Şahin (2023), various sector indices belonging to the Borsa Istanbul (BIST) and some criteria of these sectors were considered. Rankings were made from the sector with the highest importance degree to the one with the lowest. It was noted that investors could use multi-criteria decision-making (MCDM) methods when making sector selections based on these importance degrees. An application regarding this matter was also presented.

Upon reviewing the existing research, it is observed that decision-making problems often arise in situations where corporate decisions are involved, such as determining the location and staffing of companies or identifying criteria that lead to customer loss. Consequently, efforts have been made to assist firms in making the right decisions, yielding successful outcomes. However, in studies focusing on investment, Multi-Criteria Decision Making (MCDM) problems have been employed without leveraging the uncertainty provided by neutrosophic sets. This is where the significance of this study and its distinction from others become evident. The study aims not only to address the needs of companies or institutions but also to cater to individuals or legal entities interested in investing in the stock market. Furthermore, it considers verbal uncertainty in the decision-making process. As previous studies have shown, selecting stocks in the stock market is a decision-making problem. A review of the literature indicates that there has not been a decision-making problem that integrates neutrosophic sets with MCDM approaches. This study seeks to address this gap in the literature.

MATERIALS AND METHODS

Neutrosophic Set Theory

Neutrosophic set theory was introduced by Smarandache in 1995. One of the reasons for the emergence of neutrosophic set theory is the quest to deal with uncertainties and effectively model complex problems. This theory aims to mathematically express situations involving uncertainty, particularly. Neutrosophic set theory extends the intuitive fuzzy set theory by considering situations where elements are partially members, in addition to being fully or not fully members. Neutrosophic set is a generalized form of fuzzy set and intuitionistic fuzzy set (Smarandache, 1998; Smarandache, 2004).

Neutrosophic set theory is defined through three independent functions, namely the truth, falsity, and indeterminacy functions, within the interval $]0^-, 1^+[$ (Smarandache, 1998). For a neutrosophic set $\tilde{A}$ derived from the universal set X, $T_{\tilde{A}}(x): X \rightarrow]0^-, 1^+[$, $I_{\tilde{A}}(x): X \rightarrow]0^-, 1^+[$ and $F_{\tilde{A}}(x): X \rightarrow]0^-, 1^+[$ are the truth, indeterminacy, and falsity membership functions, respectively. $T_{\tilde{A}}(x), I_{\tilde{A}}(x)\ ve\ F_{\tilde{A}}(x)$ functions are the real standard or non-standard subset of the non-standard $]0^-, 1^+[$ interval, with no limitation on their sum (Smarandache, 1998; Can and Özgüven, 2017). There fore, $0^- \leq inf\ T_{\tilde{A}} + inf\ I_{\tilde{A}} + inf\ F_{\tilde{A}} \leq sup\ T_{\tilde{A}}(x) + sup\ I_{\tilde{A}}(x) + supF_{\tilde{A}}(x) \leq 3^+$ holds (Smarandache, 1998). Single valued neutrosophic sets are a subset type of neutrosophic sets and were developed by (Wang et al. 2010) for the application of neutrosophic sets in real-life problems.

Let $\tilde{A}$ be a single valued neutrosophic set derived from the universal set X. For the set $\tilde{A}$, let the functions be defined as follows: $T_{\tilde{A}}(x): X \rightarrow [0,1]$, $I_{\tilde{A}}(x): X \rightarrow [0,1]$ and $F_{\tilde{A}}(x): X \rightarrow [0,1]$:

It is considered that $0 \leq T_{\tilde{A}}(x) + I_{\tilde{A}}(x) + F_{\tilde{A}}(x) \leq 3$ (Wang, vd., 2010; Can ve Özgüven, 2017).

$\tilde{A}_1 = (T_1(x), I_1(x), F_1(x))$ and $\tilde{A}_2 = (T_2(x), I_2(x), F_2(x))$ The operations defined for two single valued neutrosophic sets are given below. (Smarandache, vd., 2016).

$\tilde{A}_1$and $\tilde{A}_2$ The sum of two neutrosophic sets

$\tilde{A}_1 + \tilde{A}_2 = (T_1(x) + T_2(x) - T_1(x).T_2(x), I_1(x).I_2(x), F_1(x).F_2(x))$,

$\tilde{A}_1$and $\tilde{A}_2$ The product of two neutrosophic sets;

$\tilde{A}_1 * \tilde{A}_2 = (T_1(x).T_2(x), I_1(x) + I_1(x) - I_1(x).I_2(x), F_1(x) + F_2(x) - F_1(x).F_2(x))$,

$\tilde{A}_1$ The multiplication of a neutrosophic set by a scalar k

$k * \tilde{A}_1 = \left(1 - (1 - T_1(x))^k, (I_1(x))^k, (F_1(x))^k\right),\ k > 0$,

$\tilde{A}_1$ The k th power of a neutrosophic set;

$\tilde{A}_1{}^k = \left((T_1(x))^k, 1 - (1 - I_1(x))^k, 1 - (1 - F_1(x))^k\right), k > 0$,

$\tilde{A}_1$ The complement of a neutrosophic set;

$\tilde{A}_1^{\hat{C}} = \left\{(T_1(x))^{\hat{C}}, (I_1(x))^{\hat{C}}, (F_1(x))^{\hat{C}}\right\}$,

$\tilde{A}_1$ and $\tilde{A}_2$ The union of two neutrosophic sets;

$\tilde{A}_1 \tilde{\cup} \tilde{A}_2 = \left\{\langle x, T_{\tilde{A}_1 \tilde{\cup} \tilde{A}_2}(x), I_{\tilde{A}_1 \tilde{\cup} \tilde{A}_2}(x), F_{\tilde{A}_1 \tilde{\cup} \tilde{A}_2}(x) \rangle : x \in X\right\}$.

Here $T_{\tilde{A}_1 \tilde{\cup} \tilde{A}_2}(x) = max\{T_{\tilde{A}_1}(x), T_{\tilde{A}_2}(x)\}$, $I_{\tilde{A}_1 \tilde{\cup} \tilde{A}_2}(x) = min\{I_{\tilde{A}_1}(x), I_{\tilde{A}_2}(x)\}$, $F_{\tilde{A}_1 \tilde{\cup} \tilde{A}_2}(x) = min\{F_{\tilde{A}_1}(x), F_{\tilde{A}_2}(x)\}$.

$\tilde{A}_1$ and $\tilde{A}_2$ The intersection of two neutrosophic sets;

$\tilde{A}_1 \tilde{\cap} \tilde{A}_2 = \left\{\langle x, T_{\tilde{A}_1 \tilde{\cap} \tilde{A}_2}(x), I_{\tilde{A}_1 \tilde{\cap} \tilde{A}_2}(x), F_{\tilde{A}_1 \tilde{\cap} \tilde{A}_2}(x) \rangle : x \in X\right\}$,

It is defined as follows.

Here $T_{\tilde{A}_1 \tilde{\cap} \tilde{A}_2}(x) = min\{T_{\tilde{A}_1}(x), T_{\tilde{A}_2}(x)\}$, $I_{\tilde{A}_1 \tilde{\cap} \tilde{A}_2}(x) = max\{I_{\tilde{A}_1}(x), I_{\tilde{A}_2}(x)\}$, $F_{\tilde{A}_1 \tilde{\cap} \tilde{A}_2}(x) = max\{F_{\tilde{A}_1}(x), F_{\tilde{A}_2}(x)\}$.

Neutrosophic AHP Method

The Analytic Hierarchy Process (AHP) method, one of the multi-criteria decision-making (MCDM) methods, was developed by Saaty (1980). Neutrosophic AHP aims to obtain more realistic results by addressing uncertainty in complex decision-making processes and taking into account participants' subjective responses to uncertainty. This method involves evaluating the relationships between a series of criteria and sub-criteria and attempts to determine the preference ranking using neutrosophic evaluations provided by participants. The goal of Neutrosophic AHP is to manage uncertainty and subjective evaluations better to make more robust and informative decisions. In the AHP method, pairwise comparison matrices are used to determine the importance weights of the identified criteria and sub-criteria. A scale from 1 (equally important) to 9 (absolutely important) is used in the pairwise comparison matrix. In Neutrosophic AHP theory, neutrosophic set theory is integrated into the AHP method. The data for the pairwise comparison matrix are determined using the neutrosophic score scale proposed by Radwan et al. (2016). The neutrosophic scale is shown in Table 1.

Table 1. Verbal variables and neutrosophic ımportance scale

Verbal İmportance	**(*T,I,F*) for Neutrosophic Scale**	**(*T,I,F*) for Neutrosophic Correspondence Scale**
Equally important (E)	(0.50 0.50 0.50)	(0.50 0.50 0.50)
İntermediate value (EO)	(0.55 0.40 0.45)	(0.45 0.60 0.55)
Moderately important (O)	(0.60 0.35 0.40)	(0.40 0.65 0.60)
İntermediate value (OK)	(0.65 0.30 0.35)	(0.35 0.70 0.65)
Strongly important (K)	(0.70 0.30 0.30)	(0.30 0.70 0.70)
İntermediate value (KCK)	(0.75 0.25 0.25)	(0.25 0.75 0.75)
Very Strongly important (CK)	(0.80 0.25 0.20)	(0.20 0.75 0.80)
İntermediate value (CKKe)	(0.85 0.20 0.15)	(0.15 0.80 0.85)
Definitely important (Ke)	(0.90 0.10 0.10)	(0.10 0.90 0.90)

Source: Radwan, vd.,2016

The calculation steps of Neutrosophic AHP are shown below. The steps of the neutrosophic AHP method used in the study are taken from the article (Toptancı, Ş., et al., 2018).

Step 1: A pairwise comparison matrix among the identified criteria is formed by decision-makers using the relevant neutrosophic scores based on the verbal opinions in Table 1. Equation 1 provides the neutrosophic pairwise comparison matrix.

$$\tilde{A}_{NKM} = [\widetilde{A_{ij}}]_{nxn} \tag{1}$$

(*NKM: Neutrosophic Decision Matrix*)

In Equation (1), assuming there are n criteria, $\widetilde{A_{ij}}$ $i.$ represents the weight of criterion i in the j. th column. Here, when $i = j$, indicating the weight of the same criterion itself, it takes the value $\widetilde{A_{ij}} = (0.50,0.50,0.50)$ since the weight is equal.

Step 2: In cases where there are multiple decision-makers, the evaluation results of all decision-makers are combined using the geometric mean to assess without information loss. This process can be calculated using Equation 2 below.

$$\widetilde{k_{ijNKM}} = (\hat{k}_{ij}^{1} * \hat{k}_{ij}^{2} * \hat{k}_{ij}^{3} * \ldots * \hat{k}_{ij}^{m})^{1/n} = (T_{ij}, I_{ij}, F_{ij}) \quad \text{(k: Decision makers)} \tag{2}$$

Step 3: To verify the consistency of the neutrosophic decision matrix resulting from the combination of decision-makers' evaluations, consistent preference relations are calculated using the method developed by Xu and Liau (2014) and further enhanced by (Radwan et al. 2016). In this study, the method proposed by Radwan and colleagues (2016) was employed to establish a consistent pairwise comparison matrix based on the values of the pairwise comparison matrix. The Consistency Ratio (C.R.) is calculated using the equation provided in Equation 3. For the comparison matrix to be consistent, the consistency ratio should be less than 0.10.

$$C.R. = \frac{1}{2(n-1)\cdot(n-2)} \Sigma_{i=1}^{n} \Sigma_{j=1}^{n} \left(\left| T'_{ij} - T_{ij} \right| + \left| I'_{ij} - I_{ij} \right| + \left| F'_{ij} - F_{ij} \right| \right) \quad (3)$$

Step 4: After checking the consistency of the comparison matrix, the totals of each column are calculated. Then, the weights of the criteria within the column are calculated by dividing each element of the matrix by the total in its respective column using the following equation 4.

$$\widetilde{c_{\iota\jmath NA}} = \frac{(T,I,F)}{\sum_{j}^{n}(T,I,F)} \quad \textit{(NA: Neutrosophic Weights)} \quad (4)$$

Step 5: In this step, the neutrosophic criterion weights are calculated by taking the averages of each row using the following equation (5).

$$\widetilde{w_{JNA}} = \frac{\sum_{j=1}^{n} \widetilde{c_{\iota\jmath} NA}}{n} \quad \textit{(JNA: Neutrosophic Weights of Criteria)} \quad (5)$$

Neutrosophic TOPSIS Method

The TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) method was developed by Hwang and Yoon in 1981 to solve multi-criteria decision-making (MCDM) problems. This method is used to select the best alternative among alternatives. To determine the best alternative, it identifies the most suitable alternative that is closest to the positive ideal solution and furthest from the negative ideal solution.

The initiation of combining neutrosophic set theory with the TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) method aims to transform evaluative assessments made by decision-makers using verbal expressions into neutrosophic scores, as illustrated in Table 2 below.

Table 2. Verbal expressions used for evaluating alternatives and corresponding neutrosophic scores

Verbal expressions	(T, I, F) for Neutrosophic scale
Extremely weak (AZ)	(0.10 0.90 0.90)
Too weak (CZ)	(0.20 0.85 0.80)
Weak (Z)	(0.30 0.75 0.70)
Below middle (OA)	(0.40 0.65 0.60)
Middle (O)	(0.50 0.50 0.50)
Above middle (OU)	(0.60 0.35 0.40)
Good (I)	(0.70 0.25 0.30)
Very good (CI)	(0.80 0.15 0.20)
Exremely good (AI)	(0.90 0.10 0.10)

Source: Şahin ve Yiğider, 2014

The steps of the Single-Valued Neutrosophic TOPSIS method for n alternatives (candidates) and m criteria can be summarized as follows (Şahin and Yiğider, 2014; Biswas et al., 2016).

Step 1: In the first step, a neutrosophic decision matrix is created for decision-makers.

Step 2: In the case of multiple decision-makers, the geometric mean of the neutrosophic score values provided by the decision-makers for the relevant alternative (candidate-criterion) comparison is taken to obtain the aggregated neutrosophic decision matrix.

Step 3: Using the criteria weights obtained from Neutrosophic AHP, a weighted aggregated decision matrix is created.

Step 4: To indicate the J1 beneficial criteria and J2 non-beneficial criteria, create the neutrosophic positive ideal (NPI) and neutrosophic negative ideal (NNI) solutions.

Step 5: The distance between the positive ideal solution and the negative ideal solution with alternatives is calculated using the vertex formula method for the distance between two triangular fuzzy numbers.

Step 6: Calculate the closeness coefficients (CCi) for each alternative.

$$CC_i = \frac{s_i^-}{s_i^+ + s_i^-} \text{ (Distance to the negative ideal solution)} \qquad 0 \leq CCi \leq 1 \qquad (6)$$

Step 7: Ranking of alternatives is performed based on the calculated distance coefficients.

Application

In this study, the aim is to rank some of the real estate companies traded on the Borsa Istanbul (BIST) based on their past financial performances for investment suitability under optimal conditions. Following discussions with stock market investment experts, it was asked which financial ratios are important for real estate companies and why they are important. They were also asked to rank these ratios in order of importance. Six ratios that were commonly identified as important were selected as the criteria for the problem. A summary of the analyses conducted by experts for these selected criteria is as follows: A high current ratio shows a company can cover short-term liabilities, indicating financial stability, while a low ratio may signal liquidity risk. The price-to-earnings ratio helps determine if a stock is overvalued or undervalued and can reflect growth expectations. The market value-to-book value ratio assesses asset valuation. The net profit margin measures profitability and cost management efficiency. The return on equity indicates efficient use of equity and profitability, while the return on assets measures the effectiveness of asset utilization. These criteria are essential for comprehensive financial analysis, and hence were chosen by stock market experts. Additionally, experts were asked to select the importance ratios provided in Table 1 for the prioritization of these criteria. As a result of these discussions, 6 criteria were identified, namely Current Ratio, Price/Earnings Ratio, Market Value/Book Value, Net Profit Margin, Return on Equity, and Return on Assets. These identified criteria are presented in Table 3.

Table 3. Criteria determining financial conditions for real estate companies

Cod	Criteria
(CO)	Current rate
(F/K)	Price/Earnings
(PD/DD)	Market value/Book value
(NK)	Net profit margin
(ÖK)	Return on equity
(AK)	Return on assets

After the criteria were determined, the verbal expressions provided by the decision-makers for the criteria are given in Table 4.

Table 4. Verbal expressions provided by decision-makers for criteria

Criteria	Decider 1 (KV1)	Decider 2 (KV2)	Decider 3 (KV3)
(CO)	K	OK	O
(F/K)	KCK	CK	CK
(PD/DD)	KCK	O	K
(NK)	E	EO	EO
(ÖK)	Ke	CKKe	Ke

To convert the ratios determined by decision-makers using verbal expressions into neutrosophic scores, the neutrosophic importance scale of the verbal variables provided in Table 1 was used. The neutrosophic values corresponding to the verbal expression are presented in Table 5.

Table 5. Neutrosophic scores of the criteria

Criteria	Decider 1 (KV1)	Decider 2 (KV2)	Decider 3 (KV3)
(CO)	(0.70 0.30 0.30)	(0.60 0.35 0.40)	(0.60 0.35 0.40)
(F/K)	(0.75 0.25 0.25)	(0.80 0.25 0.20)	(0.80 0.25 0.20)
(PD/DD)	(0.75 0.25 0.25)	(0.60 0.35 0.40)	(0.70 0.30 0.30)
(NK)	(0.50 0.50 0.50)	(0.55 0.40 0.45)	(0.55 0.40 0.45)
(ÖK)	(0.90 0.10 0.10)	(0.85 0.20 0.15)	(0.90 0.10 0.10)
(AK)	(0.60 0.35 0.40)	(0.60 0.35 0.40)	(0.65 0.30 0.35)

In the conducted study, the evaluation scores of 3 decision-makers were combined using the geometric mean, and they are presented in Table 6 below.

Table 6. Combined neutrosophic scores of the criteria

Criteria	Aggregated neutrosophic scores
(CO)	(0.63 0.33 0.36)
(F/K)	(0.78 0.25 0.21)
(PD/DD)	(0.68 0.29 0.31)
(NK)	(0.53 0.43 0.46)
(ÖK)	(0.88 0.12 0.11)
(AK)	(0.61 0.33 0.38)

Decision-makers determined which criterion is more important than another criterion based on the neutrosophic scores, and a pairwise comparison matrix was created. The matrix is presented in Table 7.

Table 7. Pairwise comparison matrix

Criteria	(CO)	(F/K)	(PD/DD)	(NK)	(ÖK)	(AK)
(CO)	0.50 0.50 0.50	0.30 0.70 0.70	0.40 0.65 0.60	0.75 0.25 0.25	0.25 0.75 0.75	0.55 0.40 0.45
(F/K)	0.70 0.30 0.30	0.50 0.50 0.50	0.60 0.35 0.40	0.85 0.20 0.15	0i25 0.75 0.75	0.55 0.40 0.45
(PD/DD)	0.60 0.35 0.40	0.40 0.65 0.60	0.50 0.50 0.50	0.80 0.25 0.20	0.25 0.75 0.75	0.60 0.35 0.40
(NK)	0.25 0.75 0.75	0.15 0.80 0.85	0.20 0.75 0.80	0.50 0.50 0.50	0.10 0.90 0.90	0.15 0.80 0.85
(ÖK)	0.75 0.25 0.25	0.75 0.25 0.25	0.75 0.25 0.25	0.90 0.10 0.10	0.50 0.50 0.50	0.85 0.20 0.15
(AK)	0.45 0.60 0.55	0.45 0.60 0.55	0.40 0.65 0.60	0.85 0.20 0.15	0.15 0.80 0.85	0.50 0.50 0.50

The consistency ratio (C.R.) of the pairwise comparison matrix for the criteria has been calculated as 0.05. Since the consistency ratio is less than 0.10, the pairwise comparison matrix is consistent. Therefore, the estimated weight values for the criteria by decision-makers are considered acceptable. In the next step, the columns of the pairwise comparison matrix are summed up, and the total is presented in Table 8.

Table 8. Sum of columns of the pairwise comparison matrix

Criteria	(CO)	(F/K)	(PD/DD)	(NK)	(ÖK)	(AK)
(CO)	0.50 0.50 0.50	0.30 0.70 0.70	0.40 0.65 0.60	0.75 0.25 0.25	0.25 0.75 0.75	0.55 0.40 0.45
(F/K)	0.70 0.30 0.30	0.50 0.50 0.50	0.60 0.35 0.40	0.85 0.20 0.15	0.25 0.75 0.75	0.55 0.40 0.45
(PD/DD)	0.60 0.35 0.40	0.40 0.65 0.60	0.50 0.50 0.50	0.80 0.25 0.20	0.25 0.75 0.75	0.60 0.35 0.40
(NK)	0.25 0.75 0.75	0.15 0.80 0.85	0.20 0.75 0.80	0.50 0.50 0.50	0.10 0.90 0.90	0.15 0.80 0.85
(ÖK)	0.75 0.25 0.25	0.75 0.25 0.25	0.75 0.25 0.25	0.90 0.10 0.10	0.50 0.50 0.50	0.85 0.20 0.15
(AK)	0.45 0.60 0.55	0.45 0.60 0.55	0.40 0.65 0.60	0.85 0.20 0.15	0.15 0.80 0.85	0.50 0.50 0.50
Total	3.25 2.75 2.75	2.55 3.50 3.45	2.85 3.15 3.15	4.65 1.50 1.35	1.50 4.45 4.50	3.20 2.65 2.80

To determine the weight of each criterion relative to the other criteria in the same column, a normalized matrix was created by dividing each value in the column by the sum of the column's values. This normalized matrix is presented in Table 9.

Table 9. Normalized matrix

Criteria	(CO)	(F/K)	(PD/DD)	(NK)	(ÖK)	(AK)
	T I F	T I F	T I F	T I F	T I F	T I F
(CO)	0.15 0.18 0.18	0.11 0.20 0.20	0.14 0.20 0.19	0.16 0.16 0.18	0.16 0.16 0.16	0.17 0.15 0.16
(F/K)	0.21 0.10 0.10	0.19 0.14 0.14	0.21 0.11 0.12	0.18 0.13 0.11	0.16 0.16 0.16	0.17 0.15 0.16
(PD/DD)	0.18 0.12 0.14	0.15 0.18 0.17	0.17 0.15 0.15	0.17 0.16 0.14	0.16 0.16 0.16	0.18 0.13 0.14
(NK)	0.07 0.27 0.27	0.05 0.22 0.24	0.07 0.23 0.25	0.10 0.33 0.37	0.06 0.20 0.20	0.04 0.30 0.30
(ÖK)	0.23 0.09 0.09	0.29 0.07 0.07	0.26 0.07 0.07	0.19 0.06 0.07	0.33 0.11 0.11	0.26 0.07 0.05
(AK)	0.13 0.21 0.20	0.17 0.17 0.15	0.14 0.20 0.19	0.18 0.13 0.11	0.01 0.17 0.18	0.15 0.18 0.17

To transform the data in the matrix into a single parameter for determining the weights of the given criteria, the averages of the truth values, indeterminacy values, and falsity values of each criterion's rows in the normalized matrix are taken separately, and the normalized matrix is transformed into a single-valued matrix. The single-valued version of the normalized matrix is presented in Table 10.

Table 10. Single-valued transformation of the normalized matrix

Criteria	T	I	F
(CO)	0.14	0.17	0.17
(F/K)	0.18	0.13	0.13
(PD/DD)	0.16	0.15	0.15
(NK)	0.06	0.25	0.27
(ÖK)	0.26	0.07	0.07
(AK)	0.13	0.17	0.16

The final step of the Neutrosophic AHP method involves converting the criterion weights from their neutrosophic state to a single-valued form. This conversion process is performed according to the formula below.

$$A_K(x) = \left(1 - \sqrt{\frac{\{(1-T_N(x)^2)+I_N(x)^2+F_N(x)^2\}}{3}}\right) \tag{7}$$

According to the transformation, the weights of the criteria are shown in Table 11.

Table 11. Criterion weights

CO	0.4844
F/K	0.5148
PD/DD	0.4998
NK	0.4171
ÖK	0.5689
AK	0.4799

According to the results obtained in Table 11, the highest value is identified as OK. Following this, the values are ranked as PD/DD, F/K, CO, AK, and NK, respectively. Therefore, the most important criterion among the given criteria emerges as equity. Based on these results, when examining the financial performance of companies for investment purposes, alternatives can be evaluated according to the importance ranking mentioned above. In the next stage, when applying the neutrosophic TOPSIS method, we will use these results to find the best alternative.

After calculating the weights of the criteria, the final stage of the application will involve ranking the designated companies. In this process, the neutrosophic TOPSIS method has been utilized. At this stage, a separate evaluation form has been prepared for stock market experts to assess the companies based on the criteria. The verbal expressions provided by the experts for the companies are given in Table 12 below.

Table 12. Verbal evaluations of decision makers in comparing companies according to criteria

Criteria	Alternatıves											
	A1			A2			A3			A4		
	Kv1	Kv2	Kv3	Kv1	Kv2	Kv3	Kv1	Kv2	Kv3	Kv1	Kv2	Kv3
CO	CZ	Z	CZ	O	OU	OU	CI	CI	AI	AZ	CZ	Z
F/K	OA	O	O	OU	O	OA	OU	I	I	O	OA	OA
PD/DD	O	OA	OA	CI	I	CI	CI	CI	CI	CZ	Z	OA
NK	OA	OA	O	OU	OU	O	OU	O	OU	O	OU	OU
ÖK	Z	OA	OA	O	OU	OU	I	I	CI	OA	O	OA
AK	OU	O	OA	OU	OU	O	I	OU	O	OU	OU	O

The verbal expressions given in Table 12 were first converted into neutrosophic scores. Subsequently, to avoid data loss, the decision makers' data was combined using the geometric mean, and the neutrosophic decision matrix was created as shown in Table 13 below.

Table 13. Combined neutrosophic decision matrix

Criteria	Alternatıves											
	A1			A2			A3			A4		
	T	I	F	T	I	F	T	I	F	T	I	F
CO	0.22	0.81	0.76	0.56	0.39	0.43	0.83	0.13	0.12	0.18	0.83	0.79
F/K	0.46	0.54	0.53	0.49	0.48	0.49	0.66	0.27	0.33	0.43	0.59	0.56
PD/DD	0.43	0.59	0.56	0.76	0.17	0.22	0.80	0.15	0.20	0.28	0.74	0.69
NK	0.43	0.59	0.56	0.56	0.39	0.43	0.53	0.44	0.46	0.56	0.39	0.43
ÖK	0.36	0.68	0.63	0.56	0.39	0.43	0.73	0.21	0.26	0.43	0.59	0.56
AK	0.49	0.48	0.49	0.56	0.39	0.43	0.59	0.35	0.39	0.56	0.39	0.43

The difference between the TOPSIS and AHP methods arises during the creation of the decision matrix. In the AHP method, pairwise comparison matrices are formed among the criteria, whereas the TOPSIS method involves scoring and assigning values.

In the next step, to determine the importance weights of companies according to the criteria, the criterion weights calculated in the neutrosophic AHP method are used to create the weighted normalized matrix by multiplying each relevant element of the decision matrix. The weighted normalized matrix is shown in the table below as Table 14.

Table 14. Weighted normalized matrix

	CO			F/K			PD/DD			NK			ÖK			AK		
	T	I	F	T	I	F	T	I	F	T	I	F	T	I	F	T	I	F
A1	0.10	0.39	0.36	0.23	0.27	0.27	0.2	0.29	0.27	0.17	0.24	0.23	0.20	0.38	0.35	0.23	0.23	0.23
A2	0.27	0.18	0.20	0.25	0.24	0.25	0.37	0.08	0.10	0.23	0.16	0.17	0.31	0.22	0.24	0.26	0.18	0.20
A3	0.40	0.06	0.05	0.33	0.13	0.16	0.39	0.07	0.09	0.22	0.18	0.19	0.41	0.11	0.14	0.28	0.16	0.18
A4	0.08	0.40	0.38	0.22	0.30	0.28	0.13	0.36	0.34	0.23	0.16	0.17	0.24	0.33	0.31	0.26	0.18	0.20

The aim was to identify the alternative closest to the positive ideal solution among alternatives in order to determine how close other alternatives are to this ideal by finding their degrees of proximity. In the negative ideal solution, the aim is to identify the alternative furthest from the ideal and determine how distant other alternatives are from this ideal. The alternative closest to the positive ideal solution is considered the best alternative, whereas the alternative closest to the negative ideal solution is considered the least preferred. Similarly, the alternative farthest from the positive ideal solution is considered the least preferred, while the alternative farthest from the negative ideal solution is identified as the best alternative.

In the TOPSIS method, similar to investors having both profit and risk, there are positive ideal and negative ideal. The best alternatives or decisions are those closest to the positive ideal and farthest from the negative ideal. The best investments are those that provide the highest profit while avoiding the most risk (Lai, et al., 1994). To determine the positive ideal solution and negative ideal solution, we can select the best values for each attribute from all alternatives. When making this selection, we choose the values for the virtual positive ideal solution by selecting the highest T value with the lowest I and F values for each criterion. Similarly, for the virtual negative solution, we select the values with the lowest T value and the highest I and F values. This selection is made according to the formula below.

$$y_i^+ = \left([max_i T_{ij}], [min_i I_{ij}], [min_i F_{ij}]\right) \quad (8)$$

$$y_i^- = \left([min_i T_{ij}], [max_i I_{ij}], [max_i F_{ij}]\right) \quad (9)$$

The positive ideal and negative ideal values obtained as a result of selections made among alternatives are provided below.

$$y_i^+ = \begin{Bmatrix} \langle 0.40\ 0.06\ 0.05\rangle, \langle 0.33\ 0.13\ 0.16\rangle, \langle 0.39\ 0.07\ 0.09\rangle, \\ \langle 0.23\ 0.16\ 0.17\rangle, \langle 0.41\ 0.11\ 0.14\rangle, \langle 0.28\ 0.16\ 0.18\rangle \end{Bmatrix}$$

$$y_i^- = \begin{Bmatrix} \langle 0.08\ 0.40\ 0.38\rangle, \langle 0.22\ 0.30\ 0.28\rangle, \langle 0.13\ 0.36\ 0.34\rangle, \\ \langle 0.17\ 0.24\ 0.23\rangle, \langle 0.20\ 0.38\ 0.35\rangle, \langle 0.23\ 0.23\ 0.23\rangle \end{Bmatrix}$$

Table 15. Positive ıdeal and negative ıdeal values

Criteria	Neutrosophic positive ideal values	Neutrosophic negative ideal values
CO	⟨0.40 0.06 0.05⟩	⟨0.08 0.40 0.38⟩
F/K	⟨0.33 0.13 0.16⟩	⟨0.22 0.30 0.28⟩
PD/DD	⟨0.39 0.07 0.09⟩	⟨0.13 0.36 0.34⟩
NK	⟨0.23 0.16 0.17⟩	⟨0.17 0.24 0.23⟩
ÖK	⟨0.41 0.11 0.14⟩	⟨0.20 0.38 0.35⟩
AK	⟨0.28 0.16 0.18⟩	⟨0.23 0.23 0.23⟩

The distance between alternatives and the positive ideal solution and negative ideal solution can be calculated using the vertex formula method between two triangular fuzzy numbers (Chen, 2003:3). This formula is provided below.

$$d_i^+ = \sum_{j=1}^{n} d\left(y_{ij}, y_j^+\right) \qquad d_i^- = \sum_{j=1}^{n} d\left(y_{ij}, y_j^-\right) \qquad (i = 1,2, \ldots m) \quad (10)$$

$$d_v(\tilde{m}, \tilde{n}) = \sqrt{\frac{1}{3}[(a_1 - b_1)^2 + (a_2 - b_2)^2 + (a_3 - b_3)^2]} \quad (v: vertex) \quad (11)$$

According to the formula above, the distances of alternatives to positive ideal and negative ideal, and their relative distance values are as follows.

Table 16. d_i^+, d_i^- *and* RCC_i *values*

	A_1	A_2	A_3	A_4
d_i^+	1.585	0.574	0.047	1.120
d_i^-	0.109	0.754	1.077	0.104
$d_i^+ + d_i^-$	1.694	1.328	1.124	1.224
RCC_i	0.064	0.565	0.958	0.084

For ranking alternatives based on proximity coefficients is the final step of the neutrosophic TOPSIS method. Relative closeness coefficients can be calculated using the formula below:

$$RCC = \frac{d_i^-}{d_i^+ + d_i^-} (i = 1,2, \ldots, m) \quad (12)$$

(RCC: Relative Closeness Coefficient)

The relative closeness coefficient has been calculated using the formula above and is indicated below. Since in this study the proximity coefficients to the negative ideal are calculated, the alternative farthest from the negative ideal will be the best alternative. Therefore, the larger the relative closeness coefficient, the alternative's

RCC_1=0.064, RCC_2=0.565 RCC_3=0.958 RCC_4=0.084

As seen from the results, the alternative farthest from the negative ideal solution is A3. According to the relative closeness coefficients, the ranking of alternatives based on their financial conditions can be determined. In this case, if we rank the alternatives, it will be as follows:

$$A_3 > A_2 > A_4 > A_1$$

According to this ranking, the company with the best historical financial ratios is identified as company A_3. This company can be considered the most suitable for investment based on its financial performance.

To verify the consistency of the results, one can refer to the outcomes in Table 11, where the importance of criteria is determined using only the neutrosophic AHP method among the decision-making methods. In this table, it can be observed that the most important criteria are ranked as equity, price/earnings ratio, and market value/book value ratio, among others. It is not a coincidence that the companies with the best values in these criteria are also ranked as the best alternatives. In the next step, when selecting among the alternatives using the neutrosophic TOPSIS method, the companies with the highest criterion weights also rank highest in terms of investment suitability. This suggests that using these two different decision-making methods in an integrated manner yields results similar to using them separately. However, there may be cases where using the neutrosophic AHP and neutrosophic TOPSIS methods separately yields different results, particularly when decision-makers use high degrees of uncertainty in their verbal expressions.

RESULTS AND DISCUSSION

Investors must make decisions regarding the extent to which a company's financial performance is good for investment in the stock market. However, making this decision is not easy due to the presence of uncertainties. The neutrosophic sets used in the study provide clear and numerical values to cope with these uncertainties. One crucial point to note is that the stock market is rapidly influenced by various factors such as wars, pandemics, current news, etc. The decision-making problem in this study serves as an important source of data to make optimal decisions about a company's future based on past financial values. The findings openly present the situation of financial companies based on past criteria and their investments for the future. It was observed that the company with the highest weight criterion and the best situation according to this criterion could be the most suitable for investment, which perfectly corresponds to the results obtained, indicating that the problem was correctly solved optimally in the study. Studies in the literature have also examined the situations of companies in the stock market, and similar rankings to those in this study have been made. The most important aspect that distinguishes this study from others is the integration of the methods used in the study with neutrosophic sets. These methods provide the opportunity to make choices under uncertainty, allowing decision-makers to make more flexible decisions. While decision-makers used verbal expressions for criteria, they also had the opportunity to use verbal expressions for uncertainty functions by considering factors other than financial data.

To transparently explain the application part of the study and ensure it can be replicated, we can proceed as follows. First, certified stock market experts specializing in the economy should be selected as decision-makers. While an individual can act as the decision-maker, using experts ensures consistency in the decisions made. The individual must choose the sector they wish to invest in (in this study, the real estate sector was chosen), and the stock market experts must identify the important criteria for this sector. The importance of these criteria for the sector should be verbally rated by the experts. The status of alternative companies within the selected sector should also be verbally rated by the experts based on these criteria. The aim here is to determine the status of each alternative according to each criterion. These assessments can then be converted into neutrosophic scores, as described in the methodology, and the necessary steps can be applied. This allows the decision-maker to rank alternatives within the selected sectors based on their status, aiding in solving different decision-making problems.

CONCLUSION

One of the investment instruments today is to invest in publicly traded companies through initial public offerings (IPOs) and become a shareholder in those companies. To do this, it is important to choose the right sector and identify the company with the highest profit potential in order to increase profit margins in the future. If an investor can make their selection effectively, the likelihood of profiting from their investment increases.

The aim of this study is to select the right company in the stock market by considering companies' past financial conditions using Analytic Hierarchy Process (AHP) and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) methods, and to make the most accurate decisions for future investments. The goal is to integrate the methods used for these processes with neutrosophic sets to make the most suitable company selection.

In this study, economists have identified the most important criteria according to their significance. The importance weights of these criteria have been calculated, and by selecting four companies from the same sector, their potentials have been determined based on these criteria. The selected four companies have been evaluated using neutrosophic Analytic Hierarchy Process (AHP) and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) methods according to the established selection criteria for companies. As a result, the companies have been ranked, and the company with the potential to be the best investment vehicle has been selected.

The importance rankings obtained from the AHP and TOPSIS applications have been exactly the same. That is, the companies that received the highest and lowest scores in the performance evaluation rankings are the same companies with the highest and lowest importance rankings in both AHP and TOPSIS rankings. The conclusion to be drawn from this is that AHP and TOPSIS provide consistent results in determining importance rankings.

It has been observed in practice that AHP is a method that directly incorporates personal judgments, enables group decision-making, and takes into account the consistency of the evaluation results. Additionally, the simplicity of TOPSIS's content, the mathematical simplicity of the evaluation steps, and the ability to evaluate alternatives on different scales for each criterion constitute the positive aspects of this method. Moreover, integrating neutrosophic sets when using AHP and TOPSIS methods has enabled decision-makers to consider uncertainty situations more thoroughly and has facilitated finding a more detailed solution to this problem.

When ranking companies in the stock market, the importance of past performance is significant. Since there are many past financial data, evaluating all of them together in a systematic manner to determine which company has the best financial performance is not easy. With this study, however, selections can yield much more systematic and rapid results. Thus, verbal evaluations are quantified, and time and costs are efficiently utilized. However, there are always certain risks involved in investing in the stock market. Past performance is not a guarantee of future results. While methods help analyze data and structure your decision-making process, it is important to be cautious when investing and consider market conditions, news, and other variables.

This study aims to minimize risks and make optimal decisions in a field filled with uncertainties. It is believed that this research will contribute to future studies on uncertainty and decision-making problems. For subsequent research, the sectors in which investments are made can be changed, criteria can be determined based on the selected sector, and efforts can be made to obtain consistent results by using neutrosophic sets in conjunction with different decision-making methods. While the Istanbul Stock Exchange was used as the investment vehicle in this study, the approach can be applied to other areas as well. For example, new research could be conducted to help investors minimize risks or make the most profitable decisions according to market conditions if they wish to invest in areas such as gold, real estate, foreign currency, deposit accounts, or land instead of the stock market. These alternatives and criteria can be expanded, and the sets used can be further developed. These suggestions are intended for future research.

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Conflict of Interest

The article authors declare that there is no conflict of interest between them.

Author's Contributions

The authors declare that they have contributed equally to the article.

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