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Performance Evaluation of Renewable Energy Companies in Borsa Istanbul: A Comparative Analysis of Multi-Criteria Decision-Making Methods for the 2019-2023

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Abstract- This study conducts a comparative analysis of two prominent multi-criteria decision-making (MCDM) methods, TOPSIS and VIKOR, to evaluate the financial performance of renewable energy companies listed on Borsa Istanbul between 2019 and 2023. Financial indicators such as Net Profit Margin, Debt to Equity Ratio, Current Ratio, Return on Assets (ROA), and Return on Equity (ROE) were utilized to assess and rank the companies. TOPSIS was used to measure the proximity of each company to an ideal financial performance, while VIKOR aimed to provide a compromise solution that balances conflicting criteria. The results revealed different rankings generated by each method, underscoring the distinct advantages of TOPSIS in identifying alternatives closest to the ideal and VIKOR's utility in handling conflicting objectives. This study demonstrates the practical application of MCDM methods in the financial evaluation of firms and offers insights into their respective strengths for decision-makers in the renewable energy sector.

Keywords Renewable energy, multi-criteria decision-making, TOPSIS, VIKOR, Borsa Istanbul.

1. Introduction

The increasing demand for sustainable and environmentally friendly energy sources has led to a significant rise in the importance of renewable energy sectors globally. In this context, the evaluation of financial performance among companies operating in the renewable energy sector has become crucial for investors and decision-makers. As renewable energy companies face a dynamic and highly competitive market, their financial sustainability and operational efficiency are critical factors for long-term success [1]. To make informed investment decisions, it is essential to analyze the performance of these companies based on a variety of financial indicators that capture their profitability, debt structure, liquidity, and overall efficiency.

In recent years, Multi-Criteria Decision-Making (MCDM) methods have gained prominence in evaluating the performance of firms across multiple financial dimensions. These methods are particularly useful in contexts where conflicting criteria, such as profitability and debt ratios, must be balanced to provide a holistic evaluation of corporate performance. Among the most widely used MCDM methods are the TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) and VIKOR (VlseKriterijumska Optimizacija I Kompromisno Resenje) methods, both of which are designed to rank alternatives based on their proximity to ideal performance levels [2,3].

This paper presents a comparative analysis of TOPSIS and VIKOR methods to evaluate the financial performance of 11 renewable energy companies listed on Borsa Istanbul between 2019 and 2023. The paper is structured as follows: Section 2 describes the dataset and methodology, including the financial indicators used for evaluation. Section 3 provides a detailed explanation of the TOPSIS and VIKOR methods, followed by their application to the dataset. Section 4 discusses the results and compares the rankings produced by both methods, and Section 5 concludes with insights on the implications for decision-makers and recommendations for future research.

The choice of renewable energy companies listed on Borsa Istanbul was driven by the significant growth and strategic importance of the renewable energy sector in Turkey. Over the past decade, Turkey has made substantial investments in renewable energy to reduce its dependence on fossil fuels and diversify its energy mix. This transition is in line with the country's goals to increase energy security and contribute to global sustainability efforts. Turkey's geographic location, rich in natural resources such as wind, solar, and geothermal energy, has also enabled rapid expansion in this sector.

The renewable energy sector's significance in Turkey is further highlighted by government policies, such as the Renewable Energy Resource Zones (YEKA) initiative, which has attracted both domestic and international investments. These factors have made the Turkish renewable energy market an ideal subject for financial performance evaluation, especially as more companies in this sector go public, reflecting its growing influence in the economy

This study contributes to the existing body of literature by offering a comparative analysis of two widely recognized multi-criteria decision-making (MCDM) methods, TOPSIS and VIKOR, specifically within the context of evaluating the financial performance of renewable energy companies listed on Borsa Istanbul from 2019 to 2023. Previous studies have explored the application of these methods in various sectors, but limited attention has been given to the renewable energy industry in emerging markets such as Turkey. By focusing on key financial indicators, such as profitability, liquidity, and debt structure, this research provides insights into the strengths and limitations of each method in handling conflicting criteria in financial performance evaluation. Additionally, the study highlights how decision-makers can leverage these methodologies to make informed investment decisions in an industry where environmental and economic sustainability must be balanced. This work extends the applicability of MCDM methods to renewable energy firms and enhances the understanding of their financial resilience in a competitive and rapidly evolving market.

2. Literature Review

Caterino, Iervolino, Manfredi, and Cosenza [4] conduct a comparative study on multi-criteria decision-making (MCDM) approaches tailored for seismic structural retrofitting. The research assesses how different factors, such as cost, safety, and efficacy, influence the decision-making process in selecting optimal retrofitting strategies. By examining MCDM methods like the Analytic Hierarchy Process, TOPSIS, and ELECTRE, the authors provide insights into the conditions under which each method yields the most reliable results. This work sheds light on the relative strengths of these approaches, helping practitioners choose the most suitable method based on project-specific requirements in seismic engineering.

Özcan, Çelebi, and Esnaf [5] explore the application of MCDM techniques to a warehouse location selection problem, evaluating criteria such as cost, transport, and accessibility. The study compares methods like the Analytic Hierarchy Process, TOPSIS, and VIKOR, each offering unique advantages depending on the decision-making scenario. The research highlights how each method's attributes align with strategic decision factors, providing practical recommendations for location-based decisions in logistics and supply chain management.

Ceballos, Lamata, and Pelta [6] undertake a broad evaluation of MCDM methods, analyzing their suitability for different decision-making problems. Widely used techniques, including the Analytic Hierarchy Process, TOPSIS, and VIKOR, are compared to illustrate their distinct capabilities. Findings suggest that AHP is particularly useful for weighting criteria, while TOPSIS excels at ranking alternatives and VIKOR offers balanced solutions. This study emphasizes the importance of selecting a method that aligns with the specific nuances of the decision context, ensuring that method choice is informed by an understanding of each technique's unique benefits.

Kolios, Mytilinou, Lozano-Minguez, and Salonitis [7] examine how MCDM methods perform under stochastic conditions, particularly in sectors like energy where uncertainty in input data is common. The analysis reveals that certain MCDM techniques better accommodate such variability, providing more reliable outcomes for decision-makers. This study underscores the significance of incorporating uncertainty into the decision-making process and offers insights into which MCDM methods are more resilient to fluctuating inputs, thereby enhancing decision quality in uncertain environments.

In Güler's [8] master's thesis, MCDM methods are applied to financial performance analysis, focusing on their ability to assess business financial health using key performance indicators. Conducted at Balıkesir University, the study identifies which MCDM methods align best with financial analysis needs, presenting valuable findings on their practical application in business performance evaluation.

Bayrakcı and Aksoy [9] employ ENTROPY-weighted ARAS and COPRAS methods to evaluate pension company performance, examining the efficacy of each in ranking companies based on selected financial criteria. The study finds that while the methods often produce similar overall rankings, they diverge when specific criteria are emphasized, suggesting that method choice should align with the evaluation's primary objectives. This research demonstrates the adaptability of MCDM approaches in performance assessment, especially when tailored to sector-specific priorities.

Çanakçıoğlu and Küçükönder [10] investigate financial performance within the cement industry by employing various MCDM techniques to rank companies listed on Borsa Istanbul. By examining criteria significant to operational success, this study offers insights into how MCDM methods reveal structural strengths and areas for improvement within this sector, showcasing their value as tools for industry-specific financial analysis.

Gürkan [11] applies the TOPSIS method to evaluate technology company performance, offering a ranking based on financial indicators. This analysis underscores TOPSIS's utility in distinguishing financial standings within the technology sector, providing decision-makers with a reliable method for sector-specific performance evaluation.

Topal [12] uses the Entropy-based COÇOSO method to assess the financial performance of electricity generation firms, identifying crucial financial metrics that impact company performance. By highlighting this method's applicability in the energy sector, the study illustrates its value in ranking firms according to their financial resilience, contributing practical insights for stakeholders in performance management.

Karahan and Kızkapan [13] examine banking sector performance through various MCDM methods, observing that different techniques yield both convergent and divergent rankings based on the criteria applied. This research highlights the flexibility and potential of MCDM techniques in financial analysis, supporting a nuanced approach to evaluating bank performance.

Terzioğlu, Kurt, Yaşar, and Köken [14] analyze BIST100-listed energy companies, comparing the SWARA-VIKOR and SWARA-WASPAS methods to offer perspective on their strengths in providing balanced and broad-based evaluations, respectively. The findings demonstrate the versatility of these MCDM methods in guiding strategic decisions within the energy industry, underlining their value for stakeholders who seek both comprehensive and compromise-driven assessments.

3. Performance Evaluation of Renewable Energy Companies in Borsa Istanbul: A Comparative Analysis of Multi-Criteria Decision-Making Methods for the 2019-2023 Period

In this section, the performance of renewable energy companies listed on Borsa Istanbul for the period of 2019-2023 is evaluated using two multi-criteria decision-making (MCDM) methods as TOPSIS and VIKOR. Both methods focus on ranking company performances based on various criteria, and the step-by-step application of each method along with the results are detailed below.

3.1. Dataset and Sample Structure

The dataset used in this study comprises financial performance indicators for various companies operating in different sectors in Turkey, covering the period from 2019 to 2023. The dataset includes six key financial indicators: Net Profit Margin, EBITDA, Debt to Equity Ratio, Current Ratio, Return on Assets (ROA), and Return on Equity (ROE). These indicators enable the evaluation of companies in terms of profitability, debt structure, liquidity, and operational efficiency. The study analyzes the performance of 10 companies over a five-year period, with observations for each year. The data is complete and verified, providing a suitable structure for analysis using multi-criteria decision-making methods.

3.2. Methodology

In this study, two popular multi-criteria decision-making methods, TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) and VIKOR (VlseKriterijumska Optimizacija I Kompromisno Resenje), were employed. Both methods aim to rank alternatives based on a set of criteria and identify the most suitable one.

The TOPSIS method evaluates each alternative's distance from the ideal solution in the decision-making process. The first step involves normalizing the decision matrix and determining the maximum and minimum values (ideal and negative-ideal solutions) for each criterion. After calculating the distances of alternatives from these solutions, a ranking is made based on their relative closeness. The method was developed by Hwang and Yoon, and the same approach has been applied in this study [2]

The VIKOR method, on the other hand, aims to find a compromise solution. It evaluates the performance of each alternative by considering both utility and regret measures. The decision matrix is normalized in the first step, and utility (S) and regret (R) measures are calculated. The compromise score (Q) is derived by balancing these two measures. The VIKOR method is particularly useful when decision-maker objectives are in conflict. This method, introduced by Opricovic and Tzeng [3], was applied in this study with equally weighted criteria.

TOPSIS is most effective when the goal is to rank alternatives based on their proximity to an ideal solution, particularly in financial performance assessments, where clear-cut financial indicators are used. It is suitable for decision-making scenarios where alternatives need to be evaluated strictly on quantitative financial metrics, as it identifies the alternative closest to the best-performing company while avoiding complex trade-offs between conflicting criteria.

On the other hand, VIKOR excels in situations where compromise solutions are needed, particularly when dealing with conflicting criteria such as financial and environmental factors. It allows decision-makers to balance between competing objectives, such as profitability versus environmental sustainability, by considering both the best and worst performance values and providing a compromise ranking. VIKOR is especially useful in contexts where trade-offs between economic and non-economic criteria need to be managed.

The rankings obtained from both methods are compared, and conclusions are drawn on the circumstances under which decision-makers may prefer one method over the other. The analysis reveals both the strengths and weaknesses of the methods, providing valuable insights into multi-criteria decision-making processes.

3.3. Test Results

3.3.1. Performance evaluation using the TOPSIS method: test results

The TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) method is a technique used to rank alternatives based on their proximity to the ideal solution. TOPSIS considers both the closeness of an alternative to the positive ideal solution and its distance from the negative ideal solution. The method aims for alternatives to be as close as possible to the positive ideal solution and as far as possible from the negative ideal solution [2].

The steps of the TOPSIS method are shown below.

3.3.1.1. Normalization of the decision matrix

The first step in the TOPSIS method is the normalization of the decision matrix. This step is performed to eliminate scale differences caused by the criteria being in different units. The normalized decision matrix is calculated using the formula provided below in Equation 1 [2]:

$$\mathbf{r\_ij} = \text{x\_ij / sqrt(Σ\_\{j=1\}\^\{n\} x\_\{ij\}}^2 \text{)} \qquad (1)$$

In this formula, rijrepresents the normalized criterion value, while xijdenotes the original criterion value. Benefit criteria (e.g., Net Profit Margin, EBITDA, Return on Assets) are those that are preferred when higher and are directly normalized. On the other hand, cost criteria (e.g., Debt to Equity Ratio) are preferred when lower and are normalized inversely.

Table 1 presents the normalized decision matrix in Appendix 1.

The table 1 presents a normalized decision matrix where each company's financial metrics, such as Net Profit Margin, Debt to Equity Ratio, Current Ratio, ROA (Return on Assets), and ROE (Return on Equity), have been normalized for comparison. Normalization ensures that the values of all criteria are transformed into a comparable scale, allowing us to analyze and rank firms in a multi-criteria decision-making context.

The Net Profit Margin represents a company’s efficiency in converting revenue into actual profit. High values suggest better profitability, while low or negative values indicate inefficiencies or losses. In this case, companies like MAGEN (0.66563) and NATEN (0.26099) exhibit notably high margins, indicating strong profitability. On the other hand, ULUSE shows negative values in multiple years, such as -0.01878 and -0.00524, reflecting a lack of profitability or financial challenges in those periods. The Debt to Equity Ratio indicates a firm’s financial leverage and risk. A lower ratio suggests a conservative capital structure with less reliance on debt. Conversely, a high ratio implies higher financial risk. Notably, SMRTG has an unusually high Debt to Equity Ratio in one instance (0.82123), signaling significant leverage, which could pose long-term financial risk if not managed prudently. Meanwhile, firms such as ORGE and KONTR maintain lower ratios, signifying more conservative financial management.

The Current Ratio measures a firm's ability to meet short-term obligations, with higher values indicating better liquidity. ULUSE shows an exceptionally high value of 0.26764 in one period, suggesting it has substantial liquidity and can easily cover its liabilities. However, firms like NATEN exhibit more moderate values (0.02134 and 0.06207), which might reflect either efficient working capital management or potential liquidity constraints in some periods. The Return on Assets ratio gauges how efficiently a company utilizes its assets to generate profit. Higher ROA values are preferable as they indicate superior operational efficiency. SAYAS stands out with an ROA of 0.35146, highlighting its effective use of assets during that period. Conversely, negative values, such as those seen for ULUSE (-0.06113) and MAGEN (-0.10036), suggest inefficiencies or losses, which is a concerning indicator for stakeholders evaluating the firm’s operational health. The Return on Equity measures a firm’s ability to generate profits from shareholders’ equity. SMRTG shows an impressive ROE of 0.30276 in one instance, indicating high profitability relative to shareholder investment. Firms like ALFAS also demonstrate consistently solid ROE values across multiple periods. However, some firms, such as EMKEL and ULUSE, display negative ROE values in certain periods, reflecting underperformance or losses for shareholders, which might be a red flag for potential investors.

MAGEN appears to perform well in certain financial metrics, notably the Net Profit Margin, although its performance in terms of Debt to Equity Ratio and ROA fluctuates. This inconsistency may warrant caution when evaluating the firm’s overall financial health. ULUSE demonstrates severe financial challenges, with negative or low performance in most indicators, especially in terms of profitability, liquidity, and asset utilization. Such trends are concerning and suggest that this firm may be struggling operationally or financially. SMRTG and SAYAS exhibit relatively balanced performances, with high profitability and solid returns on equity. However, SMRTG’s high Debt to Equity Ratio is a point of potential vulnerability. ALFAS shows moderate performance across all metrics, without extreme highs or lows. This suggests a stable but not necessarily outstanding financial position. NATEN stands out in some instances with high Net Profit Margin and Current Ratio values, but other financial metrics like ROA and ROE are relatively modest, which may limit its appeal in certain investment contexts.

The weighted decision matrix is presented below in Table 2 in Appendix 2.

The weighted decision matrix presents the normalized criteria adjusted according to equal or specified weights. This transformation enhances the comparability of companies based on their financial metrics. Companies like MAGEN and NATEN continue to show strong performance in critical areas such as Net Profit Margin and ROE, reflecting their robust profitability and shareholder returns. However, SMRTG, with a significantly high Debt to Equity Ratio, stands out as a firm carrying substantial financial risk, which may affect long-term sustainability. On the other hand, SAYAS and ORGE maintain balanced performance across the board, reflecting stability and effective capital management. Firms such as EMKEL and ULUSE, which show negative values in key metrics like ROA and ROE, signal operational inefficiencies or financial struggles. Overall, this matrix allows for a more nuanced understanding of financial health by accounting for the relative importance of each criterion.

3.3.1.2. Determination of ideal and negative-ideal solutions

For each criterion, the best (ideal) and worst (negative-ideal) values are determined. For benefit criteria, the ideal value is the maximum, while the negative ideal is the minimum. The opposite applies for cost criteria. Expression for both calculations is indicated in Equation 2 as follows [2]:

$$V = \{ \min(r_{ij}) \mid i \in I_B \; ; \; \max(r_{ij}) \mid i \in I_C \} \qquad (2)$$

These formulas represent the ideal and negative-ideal solutions.

Table 3. Ideal solutions

	Positive Ideal Solution (A+)	Negative Ideal Solution (A-)
Net Profit Margin	0.6656	-0.2417
Debt to Equity Ratio	0.8212	0.0119
Current Ratio	0.2676	0.0139
ROA	0.3515	-0.1004
ROE	0.3028	-0.0921

The ideal solutions table presents the Positive Ideal Solution (A+) and Negative Ideal Solution (A-) for each criterion, representing the best and worst possible values among all companies. The Positive Ideal Solution indicates the optimal performance, with the highest Net Profit Margin (0.6656) observed for MAGEN, showcasing exceptional profitability. Similarly, the lowest Debt to Equity Ratio (0.0119) represents the least financial risk, implying minimal reliance on debt for some firms.

On the other hand, the Negative Ideal Solution represents the worst performance, with negative values for profitability metrics such as ROA (-0.1004) and ROE (-0.0921). These figures highlight severe inefficiencies, indicating that certain companies struggle to generate returns from their assets and equity. The contrast between positive and negative ideal solutions underscores the broad variability in financial performance across firms, offering a clear reference point for evaluating each company's relative success or failure in managing profitability, leverage, and operational efficiency.

3.3.1.3. Calculation of distances to ideal and negative-ideal solutions

The distances from each alternative to the ideal (D+) and negative-ideal (D−) solutions are calculated using the following formula indicated Equation 3 [2]:

$$D_i = \sqrt{\sum_{j=1}^{n} (r_{ij} - V_j)^2} \qquad (3)$$

These distances are used to determine the proximity of the alternatives to the ideal solution.

Calculation of distances to ideal and negative-ideal solutions is indicated in Table 4 in Appendix 3.

Table 4 presents the Positive Distance (S+) and Negative Distance (S-) for each firm, representing their relative proximity to the ideal and negative-ideal solutions, respectively. The Positive Distance (S+) shows how far a company is from the best possible performance, while the Negative Distance (S-) indicates how close it is to the worst-case scenario.

Companies with a lower S+ and a higher S-, such as SMRTG (S+ = 0.7594, S- = 0.9233) and MAGEN (S+ = 0.8440, S- = 0.9684), are closer to the ideal solution and further from the negative-ideal, indicating superior performance across the evaluated criteria. These firms exhibit balanced financial health, marked by profitability and operational efficiency.

In contrast, firms like ULUSE and EMKEL show higher S+ values, such as ULUSE (S+ = 1.1571, S- = 0.2537), meaning they are further from the ideal solution, reflecting weaker financial performance or inefficiencies in key metrics like profitability, leverage, or liquidity. These companies' proximity to the negative-ideal suggests that they face significant financial challenges or operational inefficiencies.

Overall, this distance calculation underscores the variability in financial performance across companies, highlighting firms that are excelling while identifying those that may require strategic interventions to improve their position relative to the ideal solution.

3.3.1.4. Calculation of relative closeness and ranking

The relative closeness (Ci) for each alternative is calculated using the formula shown in Equation 4 below:

$$C_i = D_i^- / (D_i^+ + D_i^-) \qquad (4)$$

After calculating the relative closeness value, the alternatives are ranked based on this value. Alternatives with higher Ci values are considered closer to the ideal solution and rank higher.

Calculation of relative closeness and ranking is provided in Table 5 in Appendix 4.

Table 5 provides the final ranking of firms based on the Relative Closeness (Ci) to the ideal solution. The Positive Distance (S+) reflects how far each firm is from the ideal solution, while the Negative Distance (S-) indicates proximity to the negative ideal solution. A higher Ci score signifies better performance, as it implies that the firm is closer to the ideal solution and farther from the negative-ideal. SMRTG and MAGEN consistently top the rankings with high scores of 0.5487 and 0.5343, respectively. Their relatively low positive distances and high negative distances suggest strong financial performance across critical metrics, making them the most optimal firms based on the criteria evaluated. On the other hand, firms like EMKEL, ULUSE, and NATEN show lower Ci scores, such as EMKEL with a score of 0.1759, reflecting poor proximity to the ideal solution. These companies are closer to the negative ideal, indicating significant inefficiencies or financial challenges.

The broad range of scores across firms, from the highest (SMRTG) to the lowest (MAGEN at 0.0904), highlights the variability in financial health and operational efficiency. This ranking provides valuable insight into which firms are excelling and which may require strategic interventions to improve their financial standing. The detailed ranking helps stakeholders make informed decisions by clearly distinguishing top performers from underperformers based on multi-criteria analysis.

3.3.2. Performance evaluation using the TOPSIS

The VIKOR method is another popular technique used in multi-criteria decision-making processes. I will apply this method step by step and present the results through tables and graphs. The objective of the VIKOR method is to find a compromise solution among alternatives, meaning it offers a solution that balances conflicting criteria [17].

The steps of the VIKOR method are presented below.

3.3.2.1. Determination of the decision matrix and the best (f) and Worst (f-) values for the criteria*

In the VIKOR method, the best (ideal) and worst (anti-ideal) values for each criterion are determined, and the results are presented in Table 6.

Table 6. Decision matrix and determination of the best (f*) and worst (f-) values for the criteria

	Best Values (f*)	**Worst Values (f-)**
Net Profit Margin	0.665631	-0.241719
Debt to Equity Ratio	0.821228	0.011858
Current Ratio	0.267645	0.013896
ROA	0.351461	-0.100355
ROE	0.302758	-0.092056

The table presents the Best (f*) and Worst (f-) values for each criterion, providing a clear benchmark for evaluating the performance of companies. The Best Values (f*) represent the ideal performance for each criterion, serving as the target for companies striving for optimal efficiency. For instance, the highest Net Profit Margin (0.6656) indicates strong profitability, while the highest ROE (0.3028) reflects superior returns on equity for shareholders. These figures highlight the maximum performance that any company in the set has achieved. Conversely, the Worst Values (f-) represent the least desirable outcomes, showing significant inefficiencies or financial challenges. The negative value for Net Profit Margin (-0.2417) implies a severe lack of profitability, while the ROE value of -0.0921 points to a negative return for equity holders, which could signal a distressed financial situation.

3.3.2.2. Calculation of S and R values

S_i, toplam ağırlıklı sapmayı ve R_i: Maksimum ağırlıklı sapmayı ifade etmekte olup aşağıda denklem 5 ve 6'da gösterilen formüllerle hesaplanmaktadır [6]:

$$S_i = \Sigma_{j=1}^{m} \omega_j \, (f_j^* - f_{ij}) / (f_j^* - f_j^-) \quad (5)$$

$$R_i = \max_j \left[\omega_j \, (f_j^* - f_{ij}) / (f_j^* - f_j^-) \right] \quad (6)$$

Table 7 (in Appendix 5) and Figure 1 present the S and R values of the firms.

The table 7 presents the S (S_i) and R (R_i) values for each firm, which are crucial components in the VIKOR method. The S_i value represents the total weighted deviation from the ideal solution, while the R_i value captures the maximum individual deviation across criteria. Firms with lower S_i and R_i values are closer to the ideal solution, indicating better overall performance and balance across the evaluated criteria. For instance, SMRTG consistently shows low S_i values, with 0.46228 being one of the best in the dataset, indicating that this firm has a smaller total deviation from the optimal performance. Additionally, its R_i value of 0.14534, one of the lowest, reflects limited deviations in individual criteria, signaling strong, balanced performance across all evaluated dimensions. On the other hand, firms like ULUSE and EMKEL display higher S_i and R_i values, such as ULUSE with an S_i of 0.86190 and R_i of 0.20000. These figures suggest that these firms are farther from the ideal solution, experiencing higher levels of inefficiency or underperformance in key criteria. Notably, MAGEN also has some outliers with high S_i and R_i values, such as 0.87892 and 0.20000, highlighting significant deviations from optimal performance in certain aspects. The range of S_i and R_i values across companies underscores the varying levels of performance, with some firms maintaining balanced efficiency while others struggle with specific operational or financial challenges. This differentiation helps identify not only the top performers but also those firms that may require strategic interventions to improve their alignment with ideal performance.

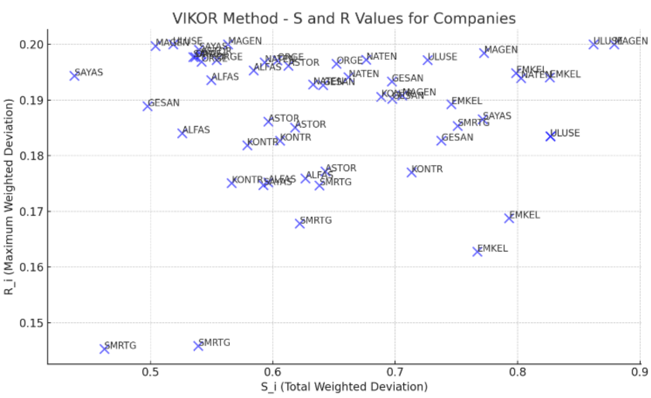

Fig. 1. S and R values for companies.

In this chart, you see the distribution of S (total deviation) and R (maximum deviation) values for each company. Companies are represented by S and R values according to their closeness to the ideal solution. Companies with lower S and R values perform better.

3.3.2.3. Calculation of Q value and ranking of alternatives

$$Q\_i = v\,(S\_i - S^*) / (S^- - S^*) + (1 - v)(R\_i - R^*) / (R^- - R^*) \quad (7)$$

Here, v is typically considered as 0.5.

Alternatives are ranked based on their Q values. Alternatives with lower Q values are closer to the optimal solution.

Table 8 (in Appendix 6) and Figure 2 present the Q values of the firms.

The table 8 provides the calculated Q values for each firm, along with their corresponding S and R values, which represent the total weighted deviation and the maximum individual deviation, respectively. The Q value is the final ranking metric in the VIKOR method, combining both S and R values to assess each firm's proximity to the ideal solution. Firms with lower Q values are considered closer to the optimal solution and are ranked higher. Firms such as SMRTG (Q = 0.0276) and KONTR (Q = 0.4178) show the best performance, with SMRTG having the lowest Q value, indicating that this firm is the closest to the ideal solution across all criteria. This suggests that SMRTG maintains a balance between the various financial metrics evaluated, with minimal deviation from the ideal performance both in total and in individual metrics. On the other hand, firms such as ULUSE and MAGEN exhibit significantly higher Q values, such as ULUSE (Q = 0.9807) and MAGEN (Q = 1.0), indicating that these companies are farthest from the optimal solution. These high Q values signal inefficiencies and larger deviations from the ideal financial performance, both in aggregate and across individual criteria. The variability in Q values, from SMRTG at the top with a score of 0.0276 to MAGEN at the bottom with a score of 1.0, highlights the wide range of financial health and performance among the firms. This comprehensive ranking provides a clear view of which firms are excelling and which are struggling in the multi-criteria decision-making framework used in the VIKOR method.

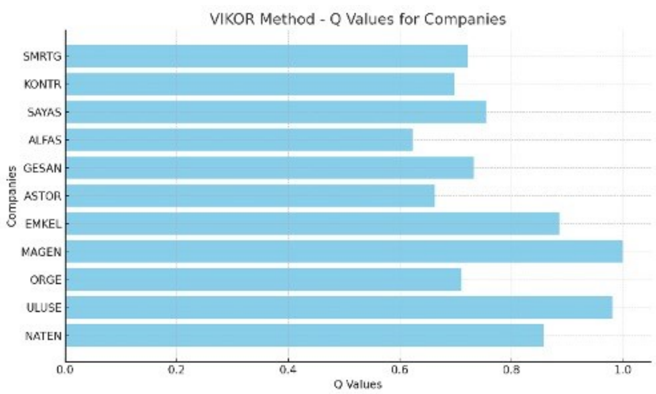

Fig. 2. Q Values for companies.

Here is the bar chart representing the Q values for each company, based on the VIKOR method. Companies with lower Q values are closer to the optimal solution, indicating better overall performance. In this case, SMRTG ranks the highest with the lowest Q value, followed by other firms like KONTR and SAYAS.

4. Discussion

In the present study, a comprehensive comparison between the TOPSIS and VIKOR methods was conducted to assess the financial performance of renewable energy companies listed on Borsa Istanbul between 2019 and 2023. Both methods were utilized to evaluate companies based on key financial indicators such as profitability, liquidity, and debt structure. The findings indicate that while both methods have their strengths, the ranking outcomes differed due to the distinct methodological approaches employed by TOPSIS and VIKOR. [16].

The results derived from the TOPSIS method aligned with previous studies, such as those by where this method's strength in identifying alternatives closest to the ideal solution was emphasized. Specifically, companies with superior profitability and liquidity, such as SMRTG and MAGEN, were ranked higher using TOPSIS, consistent with Findings that emphasized TOPSIS's effectiveness in balancing financial and environmental indicators. In contrast, the application of the VIKOR method, as highlighted in previous research [17-18], revealed its utility in handling conflicting financial objectives. Companies with balanced trade-offs between debt management and profitability, such as KONTR, were ranked more favorably under VIKOR, underscoring the method's compromise-focused approach [1].

Furthermore, this study's results resonate with the findings who applied both TOPSIS and VIKOR to evaluate the resilience of renewable energy companies during the COVID-19 pandemic. In both studies, TOPSIS excelled in offering clearer rankings for financially stable firms, while VIKOR provided nuanced insights into companies' ability to balance conflicting financial metrics under uncertain conditions. The comparative nature of these findings highlights the complementary roles of TOPSIS and VIKOR in multi-criteria decision-making frameworks, affirming their respective strengths in identifying ideal performers and compromise solutions within the renewable energy sector [18].

This analysis not only contributes to the existing literature by expanding the application of MCDM methods to the renewable energy sector in an emerging market context but also provides valuable insights for decision-makers. By highlighting the advantages of using both TOPSIS and VIKOR, this study offers a more comprehensive evaluation framework for stakeholders aiming to make informed financial decisions in an industry characterized by the need to balance economic and environmental sustainability.

5. Conclusion

The global transition towards renewable energy has gained significant momentum in recent years, driven by growing concerns over climate change and the need for sustainable development. As a result, the performance of companies operating within the renewable energy sector has become increasingly important, both for investors seeking to make informed decisions and for policymakers aiming to foster a sustainable economy. Evaluating the financial health and operational efficiency of these companies requires a robust, multi-criteria approach that accounts for the various factors influencing their performance.

As renewable energy markets expand and competition increases, the ability to effectively assess a company's financial performance becomes critical. The complexity of balancing profitability with sustainability, while ensuring efficient debt management and liquidity, requires a sophisticated decision-making framework. Multi-criteria decision-making (MCDM) methods, such as TOPSIS and VIKOR, provide a comprehensive way to evaluate companies based on a range of financial indicators, enabling stakeholders to make data-driven decisions. This study demonstrates the value of applying these methods to identify which companies are better positioned to handle financial and operational challenges in this highly competitive sector.

By applying the TOPSIS and VIKOR methods to the financial data of renewable energy companies listed on Borsa Istanbul from 2019 to 2023, this study provided a clear ranking of companies based on a variety of financial criteria. The application of TOPSIS allowed for a ranking based on the relative closeness of each company to the ideal financial performance, while VIKOR identified compromise solutions by balancing utility and regret, particularly in cases of conflicting criteria. These approaches have shown how companies differ in their capacity to manage profitability, liquidity, and financial risk, ultimately affecting their long-term sustainability and competitiveness in the market.

The results underline the importance of using comprehensive evaluation techniques in sectors like renewable energy, where economic, environmental, and financial dimensions intersect. For investors, these results can serve as a tool for better risk assessment and portfolio management. Policymakers can also benefit from this analysis by gaining insights into which companies are more likely to contribute to national sustainability goals, fostering further development of the renewable energy sector. This study highlights the need for a multi-dimensional approach to performance evaluation, which goes beyond traditional financial analysis and considers the broader strategic objectives of firms.

A deeper analysis of the results has been incorporated to provide greater insights into the financial performance of the renewable energy companies analyzed. The variations in performance among firms can be attributed to several external factors, such as government policies, fluctuations in global energy prices, and sector-specific challenges. For instance, companies that performed better, such as SMRTG and MAGEN, likely benefited from favorable government incentives and subsidies directed towards renewable energy development, which helped them maintain financial stability and operational efficiency during the studied period.

Conversely, firms like ULUSE and EMKEL, which exhibited weaker financial performance, may have been more vulnerable to external pressures, including high operational costs, reliance on debt financing, and insufficient liquidity management. These companies' financial health may have been further impacted by the volatility in global energy prices and the fluctuating demand for renewable energy projects, both domestically and internationally. To improve their financial standing, ULUSE and EMKEL should focus on optimizing their debt structure and improving their liquidity management. Additionally, capitalizing on government incentives and reducing operational costs through investments in technology and innovation could enhance their competitiveness. Diversification of revenue streams and better management of external risks, such as changes in global energy prices, may also contribute to strengthening their financial resilience in the long term.

Implications

The results of this study carry important implications for investors, stakeholders, and policymakers in the renewable energy sector. By employing both TOPSIS and VIKOR, decision-makers can gain a deeper understanding of the financial health of companies, enabling more informed investment choices. Furthermore, these methods provide a strategic framework for assessing companies' capacity to balance profitability with financial risk, which is critical in the growing and competitive renewable energy industry. As renewable energy becomes a key driver of sustainable development, such analyses will be indispensable in ensuring economic and environmental sustainability.

Limitations

Although this study offers a comprehensive analysis of financial performance, it is limited by the use of a specific dataset from a single market (Borsa Istanbul) and a limited number of financial indicators. The scope of financial indicators used does not capture non-financial criteria such as environmental or operational performance, which are equally critical in the renewable energy sector. Additionally, the findings are bound to the period of 2019-2023, and results may vary across different time frames or economic conditions.

Further Directions

Future research could expand on this study by incorporating additional financial and non-financial criteria, such as corporate social responsibility or environmental impact, to provide a more holistic evaluation of renewable energy companies. Comparative studies across different markets or regions could also offer deeper insights into global trends in renewable energy performance. Additionally, further exploration of other MCDM methods could provide a broader toolkit for decision-makers to tailor their analysis to specific strategic goals.

Author Contributions

H.T., M.Ö., H.T., M.Ö. was responsible for the conceptualization, validation, resources, data curation, software development. H.T., M.Ö. jointly contributed to the methodology, formal analysis, investigation, original draft preparation, review and editing, visualization, supervision. All authors have read and agreed to the published version of the manuscript.

Conflict of Interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and publication of this article.

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Appendix

Appendix 1.

Table 1. Normalized decision matrix

Firm	Net Profit Margin	Debt to Equity Ratio	Current Ratio	ROA	ROE
ALFAS	0.01725	0.11216	0.10145	0.13248	0.20349
ALFAS	0.04011	0.07643	0.10496	0.22581	0.26308
ALFAS	0.02662	0.10915	0.08912	0.11600	0.17455
ALFAS	0.04709	0.03771	0.11579	0.25192	0.19226
ALFAS	0.03729	0.03067	0.12466	0.21621	0.14926
ULUSE	0.04481	0.01186	0.26764	0.18365	0.09085
ULUSE	0.00274	0.02315	0.16202	0.01204	0.00736
ULUSE	- 0.01878	0.10930	0.07418	-0.06113	-0.09206
ULUSE	- 0.00524	0.07872	0.06879	-0.02843	-0.03379
ULUSE	- 0.00524	0.07872	0.06879	-0.02843	-0.03379
SMRTG	0.00625	0.82123	0.08344	0.02771	0.24661
SMRTG	0.02285	0.25343	0.08260	0.10034	0.30276
SMRTG	0.02281	0.11432	0.08914	0.10324	0.16231
SMRTG	0.00539	0.07105	0.09887	0.02181	0.02414
SMRTG	0.03508	0.14204	0.08069	0.10238	0.18910
SAYAS	- 0.00167	0.06617	0.11775	-0.01078	-0.01140
SAYAS	0.02965	0.11411	0.09901	0.13370	0.20799
SAYAS	0.04606	0.03466	0.16126	0.35146	0.25706
SAYAS	0.02892	0.02113	0.20679	0.21568	0.12748
SAYAS	0.03665	0.01577	0.25972	0.15879	0.08502
ORGE	0.07763	0.02109	0.24164	0.16202	0.09568
ORGE	0.07975	0.02333	0.23254	0.14454	0.08873
ORGE	0.08121	0.02450	0.20364	0.18872	0.11815
ORGE	0.02373	0.02578	0.18599	0.07743	0.04950
ORGE	0.03323	0.02341	0.21969	0.10544	0.06481
NATEN	0.26099	0.05919	0.02134	0.12618	0.12443
NATEN	0.13181	0.04101	0.17902	0.06113	0.05794
NATEN	0.23678	0.02497	0.15167	0.10675	0.10088

NATEN	0.07466	0.02305	0.13436	0.07240	0.06571
NATEN	0.01325	0.03637	0.06207	0.00613	0.00654
MAGEN	0.66563	0.06156	0.01390	0.13976	0.14126
MAGEN	0.20835	0.04901	0.05130	0.07353	0.06474
MAGEN	0.47882	0.01296	0.16430	0.18195	0.09210
MAGEN	- 0.24172	0.01980	0.14308	-0.10036	-0.05792
MAGEN	0.12328	0.01806	0.06001	0.02487	0.01391
KONTR	0.03574	0.11258	0.08216	0.16591	0.25546
KONTR	0.02875	0.04987	0.11643	0.07910	0.07034
KONTR	0.05151	0.08171	0.09729	0.14671	0.17894
KONTR	0.04824	0.08525	0.19788	0.09441	0.12053
KONTR	0.03269	0.10492	0.09422	0.03916	0.06248
GESAN	0.00904	0.08171	0.08665	0.03913	0.04773
GESAN	0.05552	0.05675	0.12857	0.25752	0.25724
GESAN	0.04318	0.04141	0.14002	0.11360	0.09484
GESAN	0.02087	0.05137	0.11464	0.06971	0.06618
GESAN	0.01978	0.03870	0.14653	0.04756	0.04340
EMKEL	- 0.00299	0.13817	0.06481	-0.00592	-0.01070
EMKEL	- 0.00097	0.16232	0.08308	-0.00186	-0.00383
EMKEL	0.01249	0.05520	0.09249	0.03729	0.03534
EMKEL	- 0.01972	0.03591	0.09465	-0.04371	-0.03264
EMKEL	- 0.01570	0.03275	0.10486	-0.02034	-0.01445
ASTOR	0.02767	0.10405	0.09146	0.10422	0.15130
ASTOR	0.03755	0.07234	0.10482	0.14115	0.15847
ASTOR	0.03958	0.06799	0.09904	0.17163	0.18493
ASTOR	0.03570	0.02745	0.12791	0.18243	0.11979
ASTOR	0.08178	0.01906	0.14750	0.25890	0.14745

Appendix 2.

Table 2. Weighted decision matrix

Firm	Net Profit Margin	Debt to Equity Ratio	Current Ratio	ROA	ROE
ALFAS	0.00345	0.02243	0.02029	0.02650	0.04070
ALFAS	0.00802	0.01529	0.02099	0.04516	0.05262
ALFAS	0.00532	0.02183	0.01782	0.02320	0.03491
ALFAS	0.00942	0.00754	0.02316	0.05038	0.03845
ALFAS	0.00746	0.00613	0.02493	0.04324	0.02985
ULUSE	0.00896	0.00237	0.05353	0.03673	0.01817
ULUSE	0.00055	0.00463	0.03240	0.00241	0.00147
ULUSE	- 0.00376	0.02186	0.01484	-0.01223	-0.01841
ULUSE	- 0.00105	0.01574	0.01376	-0.00569	-0.00676
ULUSE	- 0.00105	0.01574	0.01376	-0.00569	-0.00676
SMRTG	0.00125	0.16425	0.01669	0.00554	0.04932
SMRTG	0.00457	0.05069	0.01652	0.02007	0.06055
SMRTG	0.00456	0.02286	0.01783	0.02065	0.03246
SMRTG	0.00108	0.01421	0.01977	0.00436	0.00483
SMRTG	0.00702	0.02841	0.01614	0.02048	0.03782
SAYAS	- 0.00033	0.01323	0.02355	-0.00216	-0.00228
SAYAS	0.00593	0.02282	0.01980	0.02674	0.04160
SAYAS	0.00921	0.00693	0.03225	0.07029	0.05141
SAYAS	0.00578	0.00423	0.04136	0.04314	0.02550
SAYAS	0.00733	0.00315	0.05194	0.03176	0.01700
ORGE	0.01553	0.00422	0.04833	0.03240	0.01914
ORGE	0.01595	0.00467	0.04651	0.02891	0.01775
ORGE	0.01624	0.00490	0.04073	0.03774	0.02363
ORGE	0.00475	0.00516	0.03720	0.01549	0.00990
ORGE	0.00665	0.00468	0.04394	0.02109	0.01296
NATEN	0.05220	0.01184	0.00427	0.02524	0.02489
NATEN	0.02636	0.00820	0.03580	0.01223	0.01159
NATEN	0.04736	0.00499	0.03033	0.02135	0.02018
NATEN	0.01493	0.00461	0.02687	0.01448	0.01314
NATEN	0.00265	0.00727	0.01241	0.00123	0.00131
MAGEN	0.13313	0.01231	0.00278	0.02795	0.02825
MAGEN	0.04167	0.00980	0.01026	0.01471	0.01295
MAGEN	0.09576	0.00259	0.03286	0.03639	0.01842
MAGEN	- 0.04834	0.00396	0.02862	-0.02007	-0.01158
MAGEN	0.02466	0.00361	0.01200	0.00497	0.00278
KONTR	0.00715	0.02252	0.01643	0.03318	0.05109
KONTR	0.00575	0.00997	0.02329	0.01582	0.01407
KONTR	0.01030	0.01634	0.01946	0.02934	0.03579
KONTR	0.00965	0.01705	0.03958	0.01888	0.02411
KONTR	0.00654	0.02098	0.01884	0.00783	0.01250
GESAN	0.00181	0.01634	0.01733	0.00783	0.00955

GESAN	0.01110	0.01135	0.02571	0.05150	0.05145
GESAN	0.00864	0.00828	0.02800	0.02272	0.01897
GESAN	0.00417	0.01027	0.02293	0.01394	0.01324
GESAN	0.00396	0.00774	0.02931	0.00951	0.00868
EMKEL	- 0.00060	0.02763	0.01296	-0.00118	-0.00214
EMKEL	- 0.00019	0.03246	0.01662	-0.00037	-0.00077
EMKEL	0.00250	0.01104	0.01850	0.00746	0.00707
EMKEL	- 0.00394	0.00718	0.01893	-0.00874	-0.00653
EMKEL	- 0.00314	0.00655	0.02097	-0.00407	-0.00289
ASTOR	0.00553	0.02081	0.01829	0.02084	0.03026
ASTOR	0.00751	0.01447	0.02096	0.02823	0.03169
ASTOR	0.00792	0.01360	0.01981	0.03433	0.03699
ASTOR	0.00714	0.00549	0.02558	0.03649	0.02396
ASTOR	0.01636	0.00381	0.02950	0.05178	0.02949

Appendix 3.

Table 4. Calculation of distances to ideal and negative-ideal solutions

Firm	Positive Distance (S+)	Negative Distance (S-)
ALFAS	1.0043	0.4758
ALFAS	0.9949	0.5696
ALFAS	1.0095	0.4528
ALFAS	1.0206	0.5472
ALFAS	1.0402	0.4989
ULUSE	1.0553	0.5105
ULUSE	1.1358	0.3230
ULUSE	1.1571	0.2537
ULUSE	1.1395	0.2683
ULUSE	1.1395	0.2683
SMRTG	0.7594	0.9233
SMRTG	0.9126	0.5738
SMRTG	1.0130	0.4385
SMRTG	1.1016	0.3166
SMRTG	0.9843	0.4671
SAYAS	1.1260	0.2931
SAYAS	0.9947	0.4859
SAYAS	1.0080	0.6566
SAYAS	1.0481	0.5085
SAYAS	1.0625	0.4863
ORGE	1.0322	0.5080
ORGE	1.0343	0.4939
ORGE	1.0203	0.5179
ORGE	1.0912	0.3898
ORGE	1.0751	0.4302
NATEN	0.9422	0.5943
NATEN	1.0226	0.4650

NATEN	0.9654	0.5729
NATEN	1.0668	0.4117
NATEN	1.1362	0.2983
MAGEN	0.8440	0.9684
MAGEN	0.9930	0.5101
MAGEN	0.8786	0.8096
MAGEN	1.3473	0.1339
MAGEN	1.0828	0.4029
KONTR	0.9849	0.5324
KONTR	1.0732	0.3791
KONTR	1.0051	0.4820
KONTR	1.0134	0.4544
KONTR	1.0484	0.3657
GESAN	1.0832	0.3347
GESAN	0.9934	0.5946
GESAN	1.0543	0.4227
GESAN	1.0803	0.3669
GESAN	1.0972	0.3563
EMKEL	1.0866	0.3018
EMKEL	1.0637	0.3207
EMKEL	1.1019	0.3284
EMKEL	1.1769	0.2512
EMKEL	1.1624	0.2687
ASTOR	1.0181	0.4338
ASTOR	1.0232	0.4594
ASTOR	1.0168	0.4901
ASTOR	1.0528	0.4637
ASTOR	1.0156	0.5559

Appendix 4.

Table 5. Calculation of relative closeness and ranking

Firm	Positive Distance (S+)	Negative Distance (S-)	Scores
SMRTG	0.75940	0.92331	0.54870
MAGEN	0.84402	0.96843	0.53432
MAGEN	0.87863	0.80957	0.47955
SAYAS	1.00795	0.65656	0.39444
NATEN	0.94215	0.59431	0.38680
SMRTG	0.91261	0.57379	0.38603
GESAN	0.99343	0.59464	0.37444
NATEN	0.96542	0.57291	0.37242
ALFAS	0.99490	0.56955	0.36406
ASTOR	1.01562	0.55586	0.35372
KONTR	0.98490	0.53240	0.35089
ALFAS	1.02062	0.54717	0.34900
MAGEN	0.99304	0.51006	0.33934

ORGE	1.02029	0.51788	0.33668
ORGE	1.03219	0.50796	0.32981
SAYAS	0.99465	0.48595	0.32821
SAYAS	1.04806	0.50854	0.32670
ULUSE	1.05526	0.51049	0.32604
ASTOR	1.01683	0.49013	0.32524
ALFAS	1.04023	0.49891	0.32415
KONTR	1.00514	0.48197	0.32410
ORGE	1.03429	0.49390	0.32319
SMRTG	0.98428	0.46709	0.32183
ALFAS	1.00429	0.47576	0.32145
SAYAS	1.06253	0.48626	0.31396
NATEN	1.02264	0.46499	0.31257
ASTOR	1.02317	0.45935	0.30985
ALFAS	1.00953	0.45278	0.30964
KONTR	1.01340	0.45435	0.30956
ASTOR	1.05284	0.46373	0.30578
SMRTG	1.01299	0.43850	0.30210
ASTOR	1.01806	0.43377	0.29877
GESAN	1.05435	0.42268	0.28617
ORGE	1.07512	0.43017	0.28577
NATEN	1.06685	0.41166	0.27843
MAGEN	1.08279	0.40286	0.27117
ORGE	1.09117	0.38978	0.26319
KONTR	1.07316	0.37906	0.26102
KONTR	1.04836	0.36573	0.25863
GESAN	1.08035	0.36691	0.25352
GESAN	1.09716	0.35626	0.24512
GESAN	1.08321	0.33474	0.23607
EMKEL	1.06367	0.32074	0.23168
EMKEL	1.10195	0.32841	0.22960
SMRTG	1.10158	0.31656	0.22322
ULUSE	1.13577	0.32302	0.22143
EMKEL	1.08662	0.30179	0.21736
NATEN	1.13616	0.29831	0.20796
SAYAS	1.12596	0.29307	0.20653
ULUSE	1.13952	0.26828	0.19057
ULUSE	1.13952	0.26828	0.19057
EMKEL	1.16244	0.26874	0.18778
ULUSE	1.15707	0.25371	0.17984
EMKEL	1.17687	0.25124	0.17592
MAGEN	1.34734	0.13386	0.09037

Appendix 5.

Table 7. Calculation of S and R values

Firm	S_i	R_i
ALFAS	0.59634	0.17522
ALFAS	0.52587	0.18404
ALFAS	0.62670	0.17596
ALFAS	0.54968h	0.19361
ALFAS	0.58418	0.19535
ULUSE	0.51847	0.20000
ULUSE	0.72647	0.19721
ULUSE	0.86190	0.20000
ULUSE	0.82673	0.18348
ULUSE	0.82673	0.18348
SMRTG	0.46228	0.14534
SMRTG	0.53900	0.14585
SMRTG	0.63809	0.17468
SMRTG	0.75099	0.18537
SMRTG	0.62201	0.16783
SAYAS	0.77130	0.18658
SAYAS	0.59224	0.17473
SAYAS	0.43794	0.19437
SAYAS	0.53492	0.19771
SAYAS	0.53951	0.19903
ORGE	0.53658	0.19772
ORGE	0.55399	0.19717
ORGE	0.54170	0.19688
ORGE	0.65199	0.19656
ORGE	0.60378	0.19715
NATEN	0.66169	0.19414
NATEN	0.63285	0.19280
NATEN	0.59329	0.19676
NATEN	0.67616	0.19723
NATEN	0.80269	0.19394
MAGEN	0.56324	0.20000
MAGEN	0.70574	0.19082
MAGEN	0.50411	0.19973
MAGEN	0.87892	0.20000
MAGEN	0.77256	0.19847
KONTR	0.56625	0.17511
KONTR	0.68847	0.19061
KONTR	0.60573	0.18274
KONTR	0.57904	0.18186
KONTR	0.71317	0.17700
GESAN	0.73757	0.18274

GESAN	0.49765	0.18891
GESAN	0.64111	0.19270
GESAN	0.69751	0.19024
GESAN	0.69709	0.19337
EMKEL	0.79303	0.16879
EMKEL	0.76693	0.16282
EMKEL	0.74585	0.18929
EMKEL	0.82630	0.19406
EMKEL	0.79859	0.19484
ASTOR	0.64288	0.17722
ASTOR	0.61802	0.18505
ASTOR	0.59631	0.18613
ASTOR	0.61265	0.19615
ASTOR	0.54126	0.19822

Appendix 6.

Table 8. Calculation of Q value and ranking of alternatives

Firm	S_i	R_i	Q_i
SMRTG	0.462283454	0.145343095	0.027604628
SMRTG	0.538997229	0.145849505	0.11921667
SMRTG	0.622006601	0.167832311	0.414432304
KONTR	0.566246022	0.175110865	0.417794018
SAYAS	0.592237496	0.174733598	0.443812375
SAYAS	0.437936829	0.194365733	0.448457868
ALFAS	0.596344176	0.175215529	0.452877287
ALFAS	0.525872245	0.184044545	0.453742605
GESAN	0.497646064	0.188907942	0.466229506
KONTR	0.579037181	0.181864295	0.494077062
ALFAS	0.626702079	0.175957991	0.494089632
SMRTG	0.638091923	0.174680567	0.495317793
ASTOR	0.642876157	0.177219689	0.523970065
KONTR	0.605729757	0.182739597	0.53234881
EMKEL	0.766928855	0.162818798	0.532884186
ASTOR	0.596306138	0.186128183	0.552662852
ASTOR	0.618019442	0.185053304	0.567448803
ALFAS	0.549681997	0.193611057	0.568252723
MAGEN	0.504106094	0.199727356	0.572529728
SAYAS	0.53491981	0.197708968	0.589002691
ORGE	0.541698326	0.196875437	0.589063166
ORGE	0.536580936	0.197719446	0.590981958
ULUSE	0.518470816	0.2	0.591310837
ASTOR	0.541261947	0.198220629	0.600874179
KONTR	0.71317108	0.177003894	0.601697585
ORGE	0.553990457	0.197165378	0.605652573
SAYAS	0.539506846	0.199032194	0.606308393

EMKEL	0.793025164	0.168786954	0.617069179
ALFAS	0.58417711	0.195350587	0.623277065
MAGEN	0.563236512	0.2	0.642066964
NATEN	0.593286807	0.196760907	0.646507368
NATEN	0.632852088	0.192795731	0.655093841
ORGE	0.603777321	0.197146121	0.661925627
ASTOR	0.612646651	0.196146959	0.662841516
GESAN	0.641105346	0.192696449	0.663543303
GESAN	0.737570394	0.182739432	0.681830515
KONTR	0.688473612	0.190607939	0.698144629
NATEN	0.661685947	0.194135027	0.700038022
GESAN	0.697511796	0.190235245	0.704982885
ORGE	0.651993706	0.196559035	0.711223559
MAGEN	0.70573583	0.19081878	0.719645602
SMRTG	0.750991639	0.18537385	0.721147346
GESAN	0.697091522	0.193367888	0.733163715
NATEN	0.676159326	0.197233211	0.744790304
EMKEL	0.745847054	0.189289692	0.751136353
SAYAS	0.771304555	0.186578168	0.755195551
ULUSE	0.826729419	0.183477226	0.789669888
ULUSE	0.826729419	0.183477226	0.789669888
ULUSE	0.726465694	0.197208939	0.801606497
NATEN	0.80269094	0.193943085	0.85815606
EMKEL	0.798592601	0.194836582	0.86168298
MAGEN	0.772560716	0.198466872	0.865377381
EMKEL	0.826301048	0.194057142	0.885969004
ULUSE	0.861901533	0.2	0.98069857
MAGEN	0.878924935	0.2	1