Journal of Corporate Governance, Insurance, and Risk Management
https://www.acadlore.com/journals/JCGIRM

Performance Appraisal of Iron and Steel Enterprises Listed on BIST: An ENTROPY-Based TOPSIS Approach

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Received: 07-25-2024 **Revised:** 09-14-2024 **Accepted:** 09-22-2024

Citation: Özkurt Çokgüngör, H. (2024). Performance appraisal of iron and steel enterprises listed on BIST: An ENTROPY-based TOPSIS approach. *J. Corp. Gov. Insur. Risk Manag.*, *11*(3), 168-179. https://doi.org/10.56578/jcgirm110303.

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Abstract: The global iron and steel sector is currently navigating a period marked by significant volatility, driven by rising overcapacity and stagnating demand. In this challenging environment, businesses are increasingly compelled to compete not only within their local markets but also on the international stage, as the global economy becomes ever more interconnected. This necessitates a thorough evaluation of the financial performance of major firms in the iron and steel industry, particularly those listed on the Borsa İstanbul (BIST). Such assessments are critical for informing strategic decision-making within the sector. This study aims to assess the financial performance of prominent iron and steel companies traded on BIST between 2019 and 2023, employing an advanced multi-criteria decision-making (MCDM) approach. Specifically, an Improved ENTROPY method is combined with the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) to rank the fiscal performance of these enterprises. The findings indicate that EREGL stands out as the highest-performing company in terms of financial metrics over the specified period. The study offers valuable insights into the financial health and operational efficiency of iron and steel firms, providing key information for investors and policymakers in the sector. Additionally, the proposed methodology presents a robust framework for the evaluation of corporate performance in other industries facing similar global challenges.

Keywords: Iron and steel; Financial analysis; Improved ENTROPY method; Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS)

1. Introduction

The iron and steel sector in Turkey is among the leading organizations in the industrial sector. The Turkish iron and steel sector, whose infrastructure was laid in the 1930s, has played a significant role in the improvement and industrialization of the Turkish economy. The decreases and increases in the consumption of steel-consuming industries around the world are reflected in the performance of the Turkish steel sector, which is an exporting sector. For example, global trade remains weak as a result of weak global demand, the shift in consumption from goods to services following the COVID-19 pandemic, and protectionist trade policies implemented by countries. Therefore, in the current period, the global economy is facing many crises. Particularly high inflation rates globally, high external debt rates, the effects of the battle in Ukraine, high food and energy costs, climate change, the permanent effects of the COVID-19 pandemic, and the war that started in the Middle East are developments that are straining the global economic environment.

The performance of businesses is of great importance not only for themselves but also for the investors of the business and the country's economy. Financial performance can be defined as the measurement of the results of the monetary policies and activities of businesses. In addition, financial performance provides business managers with important information on issues such as healthy evaluation of the past, making investment and financing decisions for the future, and resource use. This investigation aims to define the fiscal performance of firms operating in the iron and steel sector in Turkey and traded on the ISE utilizing the TOPSIS method.

The method of this investigation was to select five companies, which are among the oldest and most established

organizations of the Turkish iron and steel sector and which are traded on the Istanbul Exchange and frequently manage to be among the top 100 companies in the iron and steel sector as a result of the research of Turkey's 500 Largest Industrial Enterprises organized annually by the Istanbul Chamber of Industry (ISO). Fiscal marks were utilized to define fiscal performance, and the ENTROPY method for objective weighting was utilized to define the weights of these marks. The financial analysis of these five different iron and steel companies was carried out by determining 11 criteria using the ratio analysis method with their financial performance and financial data by considering the five-year period together with the pandemic process. Financial structure, profitability, liquidity, and activity ratios were used in the analysis.

In this study, the weights of the criteria used in the performance evaluation of the five enterprises selected between 2019 and 2023 will be calculated with the ENTROPY method, and their performance will be ranked by year with the help of the TOPSIS method. By the same token, so as to better demonstrate the practical contribution of the performance ranking obtained with the TOPSIS method for investors, two different portfolios were created for the enterprises included in the analysis, taking into account the ranking suggested by the TOPSIS method, and the consistency of the results of the TOPSIS method was tried to be tested.

In this context, firstly, information about the iron and steel sector and financial performance was given, a literature review was conducted in which MCDM methods and problems in related articles were exemplified, and then the results obtained as a consequence of applying the ENTROPY-based TOPSIS method to the enterprises in the scope of the analysis were reported and evaluated.

2. Iron Steel Sector in the World and in Turkey

The iron and steel sector has been of great significance in the improvement of various industries and societies since ancient times. Especially when considering developing countries, the iron and steel sector has pioneered other sectors and continues to do so. The iron and steel sector, which is a significant sector for Turkey and the world, has the feature of being a locomotive sector in the global economy, the country's economy, and industrialization. The sector is of large significance for the country's economy owing to its qualities such as the widespread use of steel products, increasing consumption day by day, production of intermediate goods for the manufacturing industry, and export potential.

According to the International Standard Industrial Classification (ISIC Revised 3), the basic metal industry is included in the manufacturing industry subgroup and consists of 3 sub-sectors at a triple level under the relevant group. These sectors consist of the main iron and steel sector, the main metal industry other than iron and steel, and the metal casting industry.

The iron and steel sector usually includes the production of iron and steel by various methods, starting from the refining of iron ores and bringing them into different shapes by hot and cold forming methods. As a reflection of the rise in total economic activities worldwide and the growth in national economies, the need for housing, demand for automobiles, and demand for other iron and steel products, including white goods, increase rapidly day by day, which also increases the world's total steel production (EUROFER, 2024).

World steel production entered a period of rapid increase after 2000, under the leadership of the People's Republic of China. Figure 1 shows the course of world steel production between 1950 and 2023.

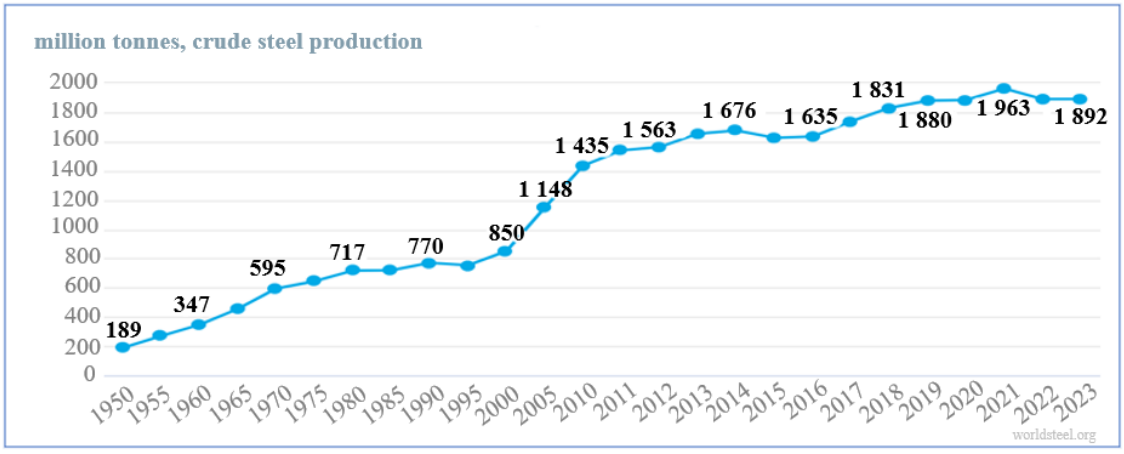

Figure 1. World steel production (1950-2023)
Source: WSA (2024)

According to Figure 1, although world steel production showed a general increase from 1950 to 1980, this trend gave way to a more fluctuating course in the 1990s. In the 2000s, world steel production increased very rapidly.

Steel production rose by 2.4% in the 1995-2000 period, 6.1% in the 2000-2005 period, and 4.3% in the 2005-2010 period. World crude steel production, which was 970 million tons in 2003, exceeded 1 billion tons for the first time in history in 2004 and rose to 1.4 billion tons in 2010. According to 2010 data, China ranks first with a 44.3% share in the total, with 626.7 million tons of crude steel production. China is followed by Japan with a 7.7% share in total crude steel production and the United States (US) with a 5.6% share. According to 2010 data, Turkey ranks 10th in world steel production with a 2% share in crude steel manufacture, with a manufacture of 29.1 million tons. When we look at the trend in steel production in recent years, a horizontal trend has been observed since 2019. The fact that total production has not exceeded the 2,000-million-ton barrier for 5 years, and that there has been no significant jump in prices in the last two years, shows that demand-side problems are the main catalyst determining steel prices. Therefore, a total of approximately 1,893 million tons of steel was produced in the world in 2023. According to the data of the World Steel Association (WSA, 2024), as of the end of 2023, China is the leader in steel production by a large margin (53.9% market share). India follows China with 7.4%, while other Asian countries account for 7.8% of production and Europe for 6.7%. Turkey's share in global production is 1.8%.

When we look at the steel sector, as global steel markets are going through a challenging period with high volatility, global excess capacity is increasing while steel demand is showing signs of stagnation. The main source of the stagnation in steel demand is the real estate crisis in China (Trading Economics, 2024). While the Chinese government's incentives have kept the industry afloat so far, a significant recovery in steel demand is yet to be seen. While China's cheap steel exports are increasing due to the weakness in demand, the decrease in the profit margin of steel producers in many countries, especially in Europe, is noteworthy. Every ton of steel not consumed in China has the potential to spill over into the global market through exports and suppress steel prices in different regions (and vice versa). During periods when China's domestic demand is weak, increasing exports puts pressure on global prices.

Iron and steel are an important sector in Turkey as well as in the world. The sector affects the level of economic development of countries owing to reasons such as its continuous technological development, its high share in world trade, the employment of a large workforce, and being a driving force for other sectors.

According to the information in Table 1, after Turkey reached the highest crude steel production amount of all time in 2021, it lost its competitive power in both the domestic and global markets and experienced a significant decrease in production in 2022 and 2023. Crude steel production, which reached 40.4 million tons in 2021, decreased by 12.9% in 2022, falling to around 35.1 million tons. This downward trend continued in 2023, and crude steel production decreased by 4% to around 33.7 million tons. In the global crude steel production ranking, it fell one place to 8th place in 2022, leaving 7th place to Germany, while there was no change in the ranking in 2023.

Table 1. Crude steel production of the Turkish iron and steel industry by year

Years	2000	2005	2010	2015	2019	2020	2021	2022	2023
Production	14,325	20,964	29,143	31,517	33,743	35,810	40,360	35,134	33,714

Source: KPMG (2024)

The most important issue on the sector's agenda on a global scale is global overcapacity, led by China. Owing to the ongoing influences of the global economic crisis, the rate of increase in steel consumption has lagged behind the increase in capacity and production and has been one of the most significant agents in the formation of a supply surplus (TCBSTB, 2022). China's focus on foreign markets due to the stagnation in its real estate market, combined with its low-cost advantage, has put downward pressure on steel prices on a global scale. Rising tensions in the Middle East are being closely monitored in neighboring countries, as the Turkish iron and steel sector is among the top three export markets (AKIB, 2024). Access to alternative markets is important for the Turkish steel sector, whose share in the European market has decreased somewhat in recent years, in terms of balancing the risks in the sector.

This situation brings with it a situation where manufacturers in Turkey have difficulty maintaining competitiveness both in export markets and in the domestic market. The fact that imports increased in quantity but decreased in amount confirms this situation. The weak trend in exports continues to put pressure on sector activities (Turkish Steel, 2024). Therefore, the fact that the well-established enterprises in the iron and steel sector are in an important and strategic position for the Turkish economy and the small number of studies covering the enterprises that make up this sector have been an encouraging factor in conducting the study. In this context, five of Turkey's oldest and well-established iron and steel enterprises will be examined.

3. Literature Review

It is seen that studies using MCDM methods are widely available in the literature in empirical research on the iron and steel industry. Macroeconomic criteria, financial indicators, and foreign trade topics stand out in the studies evaluated. However, it has been determined that in national studies on MCDM approaches regarding the iron and steel industry, topics such as financial performance, business performance, and foreign trade dominate,

while the international literature tends towards topics such as environmental performance, decarbonization technologies, and green steel production. The field of application of MCDM techniques in literature research processes finds a wide place in interdisciplinary studies and in different sectors in the literature. Therefore, the literature review of the study was carried out by filtering the iron and steel sector and some other concepts.

In accordance with the study of Çonkar et al. (2011), the correlation between the fiscal performances of firms traded in the BIST and their legal governance ratings was investigated. The fiscal ratios of the firms for the years 2007 and 2008 were converted into success scores with the help of the TOPSIS method, and the corporate among these scores and the corporate governance scores of the relevant firms was investigated. As a consequence of the evaluations, no important correlation was found between corporate governance scores and fiscal performance scores.

In the investigation conducted by Türkmen & Çağıl (2012), the fiscal performance of twelve firms listed in the Borsa Istanbul IT index was analyzed using the TOPSIS method. Financial performance ratings of the firms were made by converting the fiscal ratios computed for the period 2007-2010 into scores using the TOPSIS method.

Calvo et al. (2016) proposed a model in which criteria such as non-financial social responsibility can be taken into consideration in addition to the risk-return relationship. The authors argued that the model they created using the fuzzy optimization method offers investors alternative solutions in incorporating social, environmental, and ethical concerns into the investment decision-making process, as well as financial expectations, which has become an increasing trend in recent years.

Esmer & Bağcı (2016) analyzed the fiscal performance of all participation banks operating in Turkey between 2005 and 2014 and also determined which participation bank had higher financial performance in which year and ranked their financial performance. In the study, they used the TOPSIS method, one of the MCDM systems.

Ofluoğlu et al. (2017) tried to determine the most suitable warehouse location in terms of disaster logistics in Trabzon province. They used the ENTROPY method in the analysis of the criteria affecting the warehouse location selection and the TOPSIS method in the ranking of warehouse alternatives. In addition, the suitability of the results of the method was examined with sensitivity analysis. In the study, it was seen that the results obtained were in line with the expectations of the decision makers and the results obtained supported the expectations.

Nicolalde et al. (2022) employed the ENTROPY method, a MCDM technique, to assign weights in their research. They then evaluated a list of phase-change materials (PCMs) used in various applications and identified the most suitable material for roofing on vehicles through MCDM. After applying the ENTROPY weighting method, the results were cross-checked using a new approach based on the effect of weighting criteria removal (MEREC). To select the optimal material, decision-making methods such as VIKOR, COPRAS, and TOPSIS were utilized, and the consistency of the results was confirmed through Spearman's correlation. The study identified the savENRG PCM-HS22P as the most effective material. Simulations conducted using the finite element method revealed that increasing the PCM layer led to a 9°C reduction in indoor air temperature during heating and a 4°C improvement in temperature retention during cooling.

Singh et al. (2023), in this research, with the systematic review approach of the literature, the research articles were analyzed with the aim of exploring the status, causes, and special advantages of using TOPSIS in the pitch of materials science and engineering to achieve the aims of competitive supply chains. TOPSIS results were found to be used in 11 types of industries in India by comparing them with other MCDM methods, which are in comparison with more difficult and laborious, demonstrating the skill of the methodology of the method.

Makki & Alqahtani (2023) analyzed the impact of the COVID-19 pandemic on the fiscal performance differences of the energy sector using the 2019-2021 period data of 5 firms in the Saudi Arabian energy sector through AHP and TOPSIS methods. The study found that competence and profitability were comparatively the most significant fiscal dimensions in the effect of COVID-19 on the fiscal performance of Saudi energy firms, followed by leverage and liquidity.

Zhang et al. (2024) proposed a novel Multi-Criteria Group Decision-Making (MCGDM) method for the selection and ranking of production planning schemes. By determining the indicator weights using the AHP model, the TOPSIS method was applied. The results, based on a sampling approach, demonstrated that the MCDGM method offers a more meaningful, effective, flexible, and practical framework for evaluating and ranking production planning schemes, particularly in uncertain environments.

4. Scope of the Research

4.1. Dataset and Method of the Research

Financial proportion analysis is one of the fundamental analysis techniques widely used by investors to measure performance in stock investments. As is known, financial ratios calculated using basic financial expressions such as balance sheets and revenue statements of companies contain important information on issues such as liquidity level, asset utilization efficiency, debt level, and profitability of companies (Gürsoy, 2007). Before making an investment decision regarding any stock traded in the capital market, investors can analyze the financial statements

prepared by the companies and obtain important information about the past and current performance of the relevant company. Therefore, with the help of this financial information, investors can easily and quickly make comparisons between companies and direct their investments accordingly.

In order for businesses to survive, they need to constantly and closely monitor the rapid changes and developments occurring in the global market. Even though the methods used in crisis management are successful when applied properly, the company suffers significant losses over time, and it takes a long time to recover from the shock. When this situation is evaluated specifically for the company, it is evaluated that the company has achieved the improvement expected to occur in a long time in terms of business functions and financial performance in a short time.

For this cause, in the study conducted on the Iron and Steel Products Sectors, which are of great significance for Turkey, the performances of some enterprises operating in these sectors were measured, and comparisons were made between the enterprises after the measurement. There are many methods that can be used when making measurements. However, in this working, the Improved ENTROPY and TOPSIS methods, which are two of the MCDM methods, were utilized.

Therefore, in the scope of the working, some prominent companies traded in BIST and operating in the Iron and Steel Products Sectors were discussed, and the performances of these enterprises between 2019 and 2023 were examined (Table 2).

Table 2. Businesses operating in BIST iron and steel sector

	Stock Exchange Code	Business Name
1	BURCE	BURÇELİK BURSA ÇELİK DÖKÜM SANAYİİ A.Ş.
2	EREGL	EREĞLİ DEMİR VE ÇELİK FABRİKALARI T.A.Ş.
3	ISDMR	İSKENDERUN DEMİR VE ÇELİK A.Ş.
4	IZMDC	İZMİR DEMİR ÇELİK SANAYİ A.Ş.
5	KRDMD	KARDEMİR KARABÜK DEMİR ÇELİK SANAYİ VE TİCARET A.Ş.

Table 3. Fiscal rates utilized in the exploratory

Code	Financial Performance Indicators	Financial Ratios	TOPSIS Ideal Solution Target
C1	Current Assets / Short-Term Liabilities	Current Ratio	Max
C2	Total Debt / Total Assets	Leverage Ratio	Max
C3	Total Debt / Equity	Liquidity Ratio (Acid-Test Ratio)	Max
C4	Equity / Total Assets	Equity Ratio	Min
C5	Long Term Foreign Resources / Total Assets	Long Term Foreign Resource Rate	Max
C6	Net Sales / Total Assets	Stock Turnover Rate	Max
C7	Net Sales / Equity	Operating Profit Ratio	Max
C8	EBIT / Total Assets	Active Turnover Rate	Max
C9	EBIT / Equity	Period Profit Rate	Max
C10	Operating Profit / Equity	Equity/Return on Equity Ratio	Max
C11	Operating Profit / Total Assets	Net Profit Rate for the Period	Max

Within the scope of the working, the performance scores of these enterprises were calculated with the help of some financial ratios computed based on the balance sheets and revenue statements of the enterprises. The balance sheets and revenue statements of the firms were obtained from a formal website (www.kap.gov.tr).

Ratio analysis refers to the ratios that emerge through mathematical calculations using various financial formulas for account classes in financial statements. When performing ratio analysis, account class items in the balance sheet and revenue statement of a firm's fiscal expressions are used. This analysis method and ratios may vary in their outputs from sector to sector and company to company because the dynamics and working principles of each sector and company may not be the same. This analysis method shows the basic information and results. Interpreting the analysis results depends on the foresight, skills, and experience of company managers and individual and professional investors. As a result, interpreting these formulas, in addition to applying them to financial statements and creating new strategies, can make more positive contributions to companies or individuals. The company must maintain a balance between liquidity and profitability while conducting its operations (Uygurtürk & Korkmaz, 2012). Current Ratio: It is formulated as Current Assets / Short-Term Liabilities, and this ratio is expected to be 2. If the ratio result is below 2, it is anticipated that the company may have difficulty in fulfilling its short-term obligations (debts). Liquidity Ratio (Acid-Test Ratio): It is formulated as (Current Assets – Stocks)/Short-Term Liabilities, and the required value of this ratio is 1. Balance sheet account classes are listed from most liquid to least liquid. It is there to support the current ratio. Equity Ratio: Formulated as Equity / Total Assets. The ratio in this formula is expected to be approximately 0.5. This is how businesses are financed, and this rate is a rate that financial institutions and organizations will take into consideration when financing is needed. Long-Term Foreign Resource Ratio: It is formulated as Total U.V. Liabilities / Liabilities. There is no specific

result rate in the formula. The industry averages of the company under review can be taken into consideration as a reference. Stock Turnover: Cost of Goods Sold / Average Stocks indicate how many times the product or service produced by the company in 1 fiscal year can be converted into cash or equivalent within 1 year. Operating Profit Ratio: It is formulated as Operating Profit / Net Sales. Operating profit is one of the indicators of the efficiency and success of the business. Asset Turnover Rate: Sales/Total Assets ADH shows how many times the company collects its trade receivables in 1 fiscal year. Period Net Profit Rate: Formulated as Period N. Profit / Sales (Table 3). Net profit margin represents the level of success a business achieves as a result of its operations. The net profit margin of companies is evaluated in terms of competitor analysis by comparing them with industry averages. With the ENTROPY method, the weights of the decision criteria defined for the analysis were determined independently of the intuitive judgments and attitudes of the decision-makers.

4.2. Materials and Methods

In cases where more than one criterion is involved, methods that enable the ranking of verdict options and the selection of the best one are defined as MCDM (Meyliana et al., 2015). MCDM is utilized when there are multiple criteria and objectives involving multiple qualities and quantities in the decision problem and is applied to find solutions to these problems when the number of criteria to be regarded when making a verdict is high. While the solution methods used in the literature vary, in this investigation, the ENTROPY method was utilized to calculate the criteria weights and to enable objective weighting and to determine the weights of the data within themselves.

Afterwards, the TOPSIS method was utilized to rank the options, which is the most often utilized method in the literature. In the literature review, it is seen that these methods are often utilized in financial performance ranking. Considering the frequency of use of these methods, their suitability for the study, and ease of application, it is considered appropriate to use these methods in the study. The Improved ENTROPY method and the TOPSIS method were created as an MCDM model to examine the performance of the enterprises in the Iron and Steel Products sector in the BIST Main Metal Index, and by applying them to the verdict-making problem, the conclusions provided by the Improved ENTROPY-based model were analyzed.

The reason why the Improved ENTROPY method, which is utilized to measure the amount of useful information provided by the existing data, was chosen in practice is that it is a method that allows the objective calculation of the weight of the precious choosing criteria with the real data obtained without the need for the subjective judgments and personal evaluations of the decision-makers, and when previous studies are reviewed, it can also give extremely successful results in terms of the consistency of the results obtained. The ENTROPY method was preferred as a tool to ensure that the obtained data have a numerical scale and to calculate the weights accurately and consistently using these values in performance analysis.

4.3. Improved ENTROPY and TOPSIS Method

It has been determined that the enhanced ENTROPY technique, which is an objective weighting method, is frequently utilized in calculating the weight choosing of the criteria needed in the application phase of some MCDM techniques used in sustainability performance measurement (Feng & Wang, 2000).

The steps followed in defining the objective weights for the criteria using the ENTROPY measure are explained below, respectively.

The TOPSIS method is one of the MCDM techniques developed for ranking purposes (Hwang & Yoon, 1981). TOPSIS analysis is known as one of the MCDM methods used in the effective use and control of important elements and tools of enterprises such as labor, production, cost and profit, and especially in firm performance analysis, and the process steps of this method are explained below.

In this working, the ENTROPY and TOPSIS methods, which are MCDM methods, will be applied. The steps applied in the ENTROPY and TOPSIS methods are shown in Table 4 and Table 5.

Table 4. Steps of TOPSIS method

TOPSIS Method	
	Creating the Decision Matrix (A)
Step 1	$A_{ij} = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ a_{m1} & a_{m2} & \cdots & a_{mn} \end{bmatrix}$

	Creating the Standard Decision Matrix (R)
Step 2	$r_{ij} = \frac{a_{ij}}{\sqrt{\sum_{k=1}^{m} a_{kj}^2}} \qquad R_{ij} = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{bmatrix}$
	Creating the Weighted Standard Decision Matrix (V)
Step 3	$(\sum_{i=1}^{n} w_i = 1) \qquad V_{ij} = \begin{bmatrix} w_1 r_{11} & w_2 r_{12} & \cdots & w_n r_{1n} \\ w_1 r_{21} & w_2 r_{22} & \cdots & w_n r_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ w_1 r_{m1} & w_2 r_{m2} & \cdots & w_n r_{mn} \end{bmatrix}$
	Creating Ideal (A^+) and Negative Ideal (A^-) Solutions
Step 4	$A^* = \{(_i^{\max} v_{ij} \mid j \in J), (_i^{\min} v_{ij} \mid j \in J')\} A^* = \{v_1^*, v_2^*, \ldots, v_n^*\}$ $A^- = \{(_i^{\min} v_{ij} \mid j \in J), (_i^{\max} v_{ij} \mid j \in J')\} A^- = \{v_1^-, v_2^-, \ldots, v_n^-\}$
	Calculating Separation Measures
Step 5	$s_i^+ = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^+)^2} \rightarrow J = 1, 2, \ldots, j$ $s_i^- = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^-)^2} \rightarrow J = 1, 2, \ldots, j$
	Calculating Relative Closeness to the Ideal Solution
Step 6	$C_i^* = \frac{S_i^-}{S_i^- + S_i^*}$

Table 5. Steps of Improved ENTROPY method

Improved ENTROPY Method	
	Creating the Decision Matrix
Step 1	$z_{ij} = \frac{x_{ij} - \bar{x}_i}{\sigma_j}, \quad \forall i, j$
	Transforming the Decision Matrix into a form ready for analysis (z-score standardization process)
Step 2	$z_{ij}' = z_{ij} + A, \quad A > \lvert \min z_{ij} \rvert, \quad \forall i, j$
	Creating the Normalization Matrix
Step 3	$p_{ij} = \frac{z_{ij}'}{\sum_{i=1}^{m} z_{ij}'}, \quad \forall i, j$
	Calculating ENTROPY Values of Criteria 1
Step 4	$e_j = -k \sum_{i=1}^{m} p_{ij} \ \ln(p_{ij}), \quad k = \frac{1}{\ln(m)}, \quad \forall j$
	Calculation of Degree of Differentiation (d_j) of Information
Step 5	$d_j = 1 - e_j, \quad \forall i, j$
	Calculating Criteria Weights
Step 6	$w_j = \frac{d_j}{\sum_{j=1}^{n} d_j}, \quad \forall i, j \quad (\sum_{j=1}^{n} w_j = 1)$

The w_j values acquired with the Improved ENTROPY method, the steps of calculating the weights with the next TOPSIS method, and the steps of determining the ranking of the alternatives in the TOPSIS method are given in Table 4 and Table 5.

In the method, the C_i^* value takes value in the range of $0 \leq C_i^* \leq 1$ and after $C_i^* = 1$ shows the absolute closeness of the relevant verdict point to the ideal solution and $C_i^* = 0$ shows the absolute closeness of the relevant verdict point to the negative ideal solution, the obtained values are arranged according to the order of magnitude, and the significant orders of the decision points are determined.

5. Analysis of Research Data and Findings

5.1. Calculating Criteria Weights Using ENTROPY Method

The decision matrix of the iron and steel production enterprise, prepared according to the data obtained from the activity reports published on the Public Disclosure Platform (KAP) of the firms traded on Borsa Istanbul (BIST) and selected (Table 2) between 2019 and 2023, is as shown in Table 6.

The enhanced ENTROPY criterion weights used for each year in the study are shown in Table 7, and accordingly, the variables of the performance indicator for 2023 will be included. Financial performance indicators for the years covering the study will not be disclosed one by one and can be followed in the table (Table 7).

Table 6. Decision matrix

Years	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
2019	8,255	2,563	4,684	2,437	0,864	17,187	5,368	3,459	5,099	5,084	5,095
2020	10,100	2,589	6,341	2,411	0,863	16,626	5,487	3,491	5,209	5,134	5,202
2021	8,740	2,623	4,896	2,377	0,643	19,123	1,220	3,957	5,623	5,454	5,614
2022	7,881	2,354	3,715	2,646	0,634	25,138	5,692	5,245	5,485	5,552	5,474
2023	6,368	2,009	3,276	2,991	0,474	25,004	0,326	3,633	0,235	0,223	0,221

Table 7. ENTROPY criteria weights for the analysis period (2019-2023)

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
W-2019	0.1004	0.0924	0.1042	0.0957	0.0879	0.0875	0.0859	0.0879	0.0861	0.0860	0.0860
W-2020	0.1037	0.0920	0.1070	0.0945	0.0861	0.0909	0.0846	0.0875	0.0846	0.0846	0.0846
W-2021	0.0960	0.0909	0.0931	0.0940	0.0873	0.0940	0.0966	0.0900	0.0861	0.0860	0.0860
W-2022	0.0930	0.0928	0.0914	0.0926	0.0889	0.0923	0.0880	0.0968	0.0881	0.0880	0.0881
W-2023	0.0443	0.0057	0.1078	0.0026	0.0366	0.0922	0.1323	0.0723	0.1442	0.1965	0.1655

5.2 Application of TOPSIS Method with ENTROPY Weights

The TOPSIS application of the study was carried out separately for each year, but in order to save space, only the 2023 analyses will be included in detail. The computations made for 2023 are presented below to serve as an instance of the solution process of the six-step TOPSIS method. Similar calculations were made for the years 2019 and 2023; however, these computations were not included in the research.

In this investigation, where the fiscal performance of some firms in the Iron and Steel Sector is examined, the Improved ENTROPY method was utilized to determine the criterion weights to be utilized. While applying the method, the application was renewed for each year analyzed. Thus, the weights of the criteria were defined for each year. The weighting consequences of the advanced ENTROPY method are given in the table below.

The TOPSIS application of the study was carried out separately for each year, but in order to save space, only the 2023 analyses will be included in detail.

Table 8 provides the normalized decision matrix information for the selected companies in the iron and steel sector for 2023.

Table 8. Normalized decision matrix for 2023

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
BURCE	1.252	0.418	0.900	0.582	0.123	5.826	0.069	0.579	0.083	0.080	0.080
EREGL	1.507	0.382	0.753	0.618	0.094	2.577	0.090	0.477	0.029	0.021	0.027
ISDMR	1.525	0.366	0.685	0.634	0.088	4.373	0.084	0.654	0.052	0.054	0.052
IZMDC	0.773	0.457	0.265	0.543	0.104	7.340	0.024	1.062	0.040	0.042	0.031
KRDMD	1.311	0.386	0.673	0.614	0.065	4.888	0.059	0.861	0.031	0.026	0.031

Table 9 provides the weighted normalized decision matrix information for selected companies in the iron and steel sector for 2023.

Table 9. Weighted normalized decision matrix for 2023

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
BURCE	0.430	0.464	0.585	0.434	0.569	0.497	0.446	0.342	0.728	0.724	0.738
EREGL	0.517	0.424	0.489	0.461	0.435	0.220	0.581	0.282	0.254	0.190	0.249
ISDMR	0.524	0.406	0.445	0.473	0.407	0.373	0.543	0.387	0.456	0.489	0.480
IZMDC	0.265	0.507	0.172	0.405	0.481	0.626	0.155	0.628	0.351	0.380	0.286
KRDMD	0.450	0.428	0.437	0.458	0.301	0.417	0.381	0.509	0.272	0.235	0.286
Total	**2.187**	**2.229**	**2.128**	**2.233**	**2.192**	**2.133**	**2.105**	**2.148**	**2.061**	**2.019**	**2.038**

The *w* weight value determined in the ENTROPY analysis developed in the fourth stage of the weighted normalized decision matrix will be used in this step. The weights will be normalized by multiplying the normalized values with the *w* weight value. As a consequence of the process, positive ideal distance and negative distances will be determined and shown in Table 10. A^+: Positive ideal distance and A^-: negative ideal distance can be defined.

Table 11 shows the ideal (A^*) and negative ideal (A^-) solutions for 2023 for selected companies in the iron and steel sector.

Table 10. Weighted normalized decision matrix for 2023

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
BURCE	0.025	0.001	0.044	0.001	0.002	0.246	0.004	0.019	0.005	0.007	0.006
EREGL	0.030	0.001	0.037	0.001	0.002	0.109	0.005	0.016	0.002	0.002	0.002
ISDMR	0.031	0.001	0.034	0.001	0.001	0.184	0.005	0.022	0.003	0.005	0.004
IZMDC	0.016	0.001	0.013	0.001	0.002	0.310	0.001	0.035	0.003	0.004	0.002
KRDMD	0.027	0.001	0.033	0.001	0.001	0.206	0.004	0.028	0.002	0.002	0.002

Table 11. Determination of ideal (A^*) and negative ideal (A^-) solutions for 2023

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
Positive Ideal Solution (A^*)	0.031	0.001	0.044	0.001	0.002	0.310	0.005	0.035	0.005	0.007	0.006
Negative Ideal Solution (A^-)	0.016	0.001	0.013	0.001	0.001	0.109	0.001	0.016	0.002	0.002	0.002

Step 5: Calculating distance measurements and proximity to the solution. In this step, the positive ideal solution S^+ and negative ideal solution S^- distances are calculated. In addition, the closeness value to the ideal solution was calculated and displayed in the same table as the C^+ value, shown in Table 12, Table 13, Table 14 and Table 15. Finally, Table 16 lists the companies according to their C^+ values. C^+ rankings are listed for each year from the firm with the most successful fiscal performance to the company with the least successful fiscal performance.

In order to compare the fiscal performances of the firms in the index in the investigation in Table 17, first the weights of the selected criteria were defined with the Entropy method, which is an MCDM method, then the performances of the firms were evaluated with the TOPSIS method, and finally the success of the firms in the performance values obtained in each year was ranked on a yearly basis.

Table 12. Ideal and negative ideal solution values and company rankings in 2019

Companies	S^+	S^-	C*	Rank
BURCE	0.0661	0.1412	0.6812	**4**
EREGL	0.2021	0.0286	0.1238	**1**
ISDMR	0.1264	0.0804	0.3888	**2**
IZMDC	0.0355	0.2018	0.8504	**5**
KRDMD	0.1046	0.1009	0.4912	**3**

Table 13. Ideal and negative ideal solution values and company rankings in 2020

Companies	S^+	S^-	C*	Rank
BURCE	0.2713	0.1309	0.3254	**2**
EREGL	0.2403	0.1907	0.4425	**4**
ISDMR	0.1946	0.3017	0.6079	**5**
IZMDC	0.3010	0.2137	0.4153	**3**
KRDMD	0.2759	0.1164	0.2967	**1**

Table 14. Ideal and negative ideal solution values and company rankings in 2021

Companies	S^+	S^-	C*	Rank
BURCE	0.1792	0.1355	0.4305	**4**
EREGL	0.2693	0.1238	0.3150	**1**
ISDMR	0.2364	0.1342	0.3621	**2**
IZMDC	0.1337	0.2692	0.6681	**5**
KRDMD	0.1776	0.1282	0.4191	**3**

Table 15. Ideal and negative ideal solution values and company rankings in 2022

Companies	S^+	S^-	C*	Rank
BURCE	0.1434	0.1301	0.4758	**4**
EREGL	0.2458	0.0733	0.2297	**1**
ISDMR	0.1773	0.1031	0.3679	**3**
IZMDC	0.0757	0.2485	0.7664	**5**
KRDMD	0.1902	0.0707	0.2710	**2**

Table 16. Ideal and negative ideal solution values and company rankings in 2023

Companies	S^+	S^-	C*	Rank
BURCE	0.0661	0.1412	0.6812	**4**
EREGL	0.2021	0.0286	0.1238	**1**
ISDMR	0.1264	0.0804	0.3888	**2**
IZMDC	0.0355	0.2018	0.8504	**5**
KRDMD	0.1046	0.1009	0.4912	**3**

Table 17. 2019-2023 Success ranking of companies according to C^+ values

	2019	2020	2021	2022	2023
1	EREGL	KRDMD	EREGL	EREGL	EREGL
2	ISDMR	BURCE	ISDMR	KRDMD	ISDMR
3	KRDMD	IZMDC	KRDMD	ISDMR	KRDMD
4	BURCE	EREGL	BURCE	BURCE	BURCE
5	IZMDC	ISDMR	IZMDC	IZMDC	IZMDC

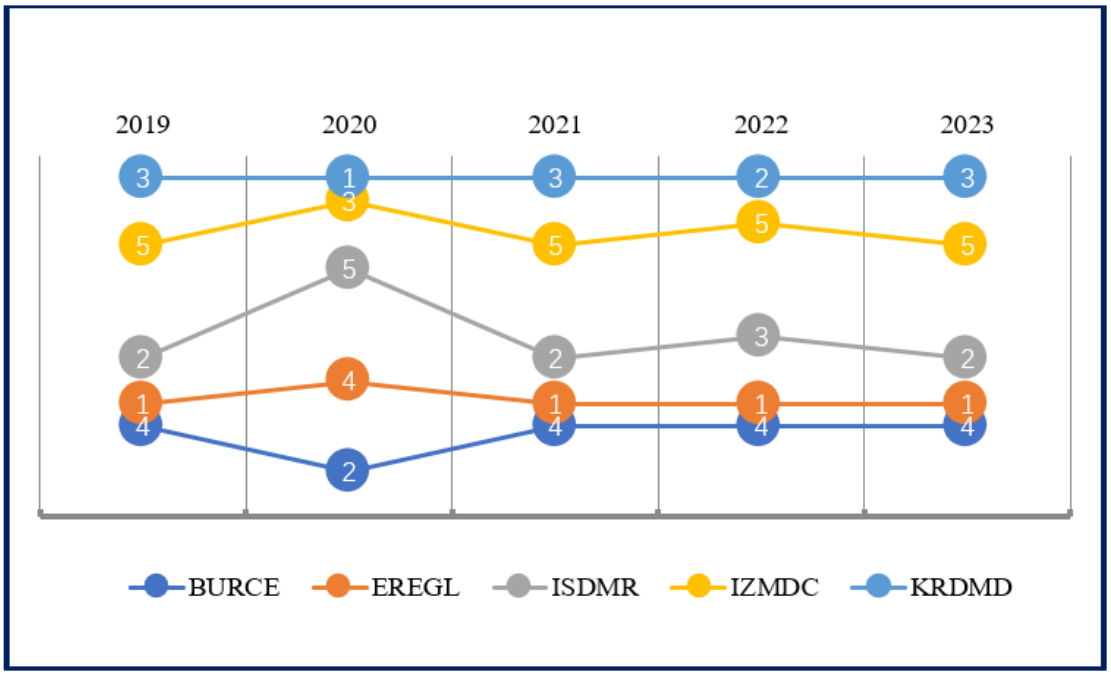

Figure 2. Performance index scores of businesses by year (2019-2023)
Note: This figure was prepared by the authors.

In the study where the Improved ENTROPY-based TOPSIS method was applied, the weightings of the criteria were recalculated for each year, and the most accurate weighting was aimed to be obtained. The empirical results of the study in Figure 2 show that EREGL is among the selected companies in the iron and steel sector with the best fiscal performance in the years 2019-2023. It is seen that the financial performance of the mentioned company is consistently in the first place, except for 2020, according to the period 2019-2023. It is seen that the company in the BURCE iron and steel sector ranked fourth in terms of financial performance in 2019-2023 and ranked second in 2020. It is seen that the performance of this company has not changed significantly over the years and continues its financial performance on the same scale compared to 2019 and 2023.

As of 2019, it is seen that EREGL is the selected company in the iron and steel sector with the best fiscal performance. Considering that the firm in question was ranked fourth in 2020, it is seen that it has increased its financial performance (Table 17). In the scope of the investigation, it is seen that the selected company in the iron and steel sector with the worst financial performance is IZDMC.

The findings obtained as a result of the analysis confirm the success of the TOPSIS method and the ratios used, and national and international developments in the sector support the consequences of the analysis. Consequently, the cost and profitability ratios used in the study produced accurate results with the Improved ENTROPY-based TOPSIS method. The study provides a methodological framework for decision-makers in the relevant sector to evaluate both their own companies and their competitors.

6. Conclusion

This investigates goals to analyze the fiscal efficiencies of iron and steel firms using the TOPSIS method. So as to analyze fiscal performance, the fiscal statements of the companies for the years 2019-2023 were examined and relevant data was obtained. In line with the 11 financial ratios (criteria) created, the weights of the criteria were first defined by the ENTROPY method. Then, the defined weights were analyzed within the scope of the TOPSIS method. The TOPSIS method used in financial performance analysis stands out as a method used to clearly reveal the differences between alternatives and to determine the relationships between decision alternatives in a simple and understandable way. When looking at the performance evaluation, it is seen that the performance of the production company has increased compared to the approaching time; it has been observed that the company is trying to increase its net sales, operating profit, and investments and sales in this axis in order to give positive momentum to its performance status.

Considering that the criteria selected in the performance evaluation of MCDM methods may vary from company to company, it is seen as a technique applicable to many production companies. When the literature review is made, it is seen that the ENTROPY method is frequently used when calculating the criteria weights. When investigations are conducted in the literature on the topics examined, it is seen that the criteria weights affecting the performance analysis are generally determined subjectively in line with the ideas of professionals or academicians. In the study, determining the criteria weights with the ENTROPY method allows the analysis to provide more objective and realistic results. The study covers only the period 2019-2023, and only some old and well-established iron and steel companies are among the limitations of the study. In the studies to be carried out on the subject, expanding the period in which the study is applied and expanding the study to include all other manufacturing sectors, such as the main metal industry, will make significant contributions to the sector and literature. In addition, it would be beneficial and contribute to the literature if researchers who will use MCDM methods test whether using the methods together in their studies on different subjects will show consistency in the results.

Data Availability

The data used to support the research findings are available from the corresponding author upon request.

Conflicts of Interest

The authors declare no conflict of interest.

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