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Research Article

PROFITABILITY PERFORMANCE ANALYSIS OF BIST MANUFACTURING SUB-SECTORS WITH DIFFERENT MULTI CRITERIA DECISION MAKING METHODS

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Abstract

The objective of the study is analyzing the profitability performances of the BIST manufacturing sub-sectors for the period 2019-2021 using different multi-criteria decision-making methods. Six profitability criteria consisting of financial ratios are determined, and the profitability performances of seven sub-sectors are examined. The weights of the evaluation criteria are calculated with CRITIC and Entropy methods, and rankings are obtained using VIKOR and TOPSIS methods. Also, to convert negative values to positive in the decision matrices z-score calculation method is applied. The results reveal that the Chemicals, Petroleum Rubber and Plastic Products sub-sector ranks the first, while the Food, Beverage and Tobacco sub-sector ranks the last in terms of profitability performance in the analyzes made using four different integrated methods. In addition, it is concluded that the ranking results of the analyzes using four different methods are similar to each other. Also, profitability performance rankings of manufacturing sub-sectors are compared with their index price performances with Spearman's rank correlation. The results show that there is no significant relationship between the index price and profitability performance rankings of the manufacturing sub-sectors for the years 2019, 2020 and 2021.

Keywords: Profitability, Financial ratios, Manufacturing sector, MCDM.

Jel Codes: M40, M41, M49.

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1. Introduction

Different businesses operating in different sectors in national economies form the basis of economic growth and development. Among these sectors, manufacturing sector is considered as the cornerstone of economic growth in terms of productivity growth, economies of scale, positive externalities, use of advanced technology and contributing to the development of other sectors in the economy (Weiss, 1988).

Turkey has been showing a reputable growth performance starting from the 1980's, and the strategic importance of the manufacturing sector is continuous. In recent years, exports played important role in the growth of Turkish economy. Increase in exports provides an increase in both employment and competition. In addition to exports, the manufacturing sector also plays an important role in the growth of our country. In our country, the largest share of the gross domestic product is taken by the manufacturing sector (Yürük & Orhan, 2020: 152). Additionally, a significant number of academic studies show that the manufacturing sector has a direct impact on economic growth (Naude & Szirmai, 2012; Kurt & Terzi, 2007; Kopuk & Meçik, 2020).

Manufacturing sector consists of companies operating in different sub-sectors connected to this sector. When the basic data of the manufacturing sector in recent years are analyzed, it is seen that the number of companies operating in this sector increased by 35.5% in the 2011-2020 period. Also, the total number of employees in the sector increased by 42% in the relevant period, reaching 3.6 million (TCMB, 2021).

Considering the importance of the manufacturing sector for our country's economy, the objective of this study is analyzing the profitability performances of BIST manufacturing sub-sectors for the period 2019-2021 and to interpret the results by making performance rankings for each year. The main reason for choosing this period is to analyze the data before the pandemic (2019) and the pandemic period (2020-2021) and to reveal the similarities and differences between these periods.

MCDM methods are frequently used in academic studies carried out in different fields in literature in recent years. The studies in which these methods are used most frequently appear as studies that include financial performance indicators of enterprises (Çakalı, 2022: 2352). In this study, six profitability criteria obtained from financial ratios are applied for seven sub-sectors. In the analysis part, primarily the CRITIC based VIKOR method is used. The reason for choosing the CRITIC based VIKOR method in the study is that this method is not used in

the financial performance evaluations of the sectors in previous studies in the literature. In addition to this method, Entropy and TOPSIS methods used in previous academic studies are also used in the study. Here, the aim is to compare the results of CRITIC based VIKOR, Entropy based VIKOR, CRITIC based TOPSIS and Entropy based TOPSIS methods used in profitability analysis of manufacturing sub-sectors in Turkey.

2. CRITIC Method

CRITIC (Criteria Importance Through Intercriteria Correlation) method is used to objectively determine criteria weights in MCDM problems. The main feature of this method is that it uses the standard deviation and correlation coefficients of the criteria together, rather than subjective expert opinions, and thus follows an objective-weighting path (Ayçin, 2019: 76).

Basic steps to be followed when using the CRITIC method are given below (Diakoulaki et al., 1995: 764-765):

Stage-1: Decision matrix, which is represented by X and consists of x_{ij} values, is created.

$$X = \begin{matrix} A_1 \\ A_2 \\ \vdots \\ A_m \end{matrix} \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2n} \\ \vdots & \vdots & \dots & \vdots \\ x_{m1} & x_{m2} & \dots & x_{mn} \end{bmatrix} \quad (1)$$

Stage-2: Normalized decision matrix is created. The criteria are divided into two groups as beneficial and non-beneficial. The normalization of the decision matrix, which is formed by using equation (2) for the beneficial and (3) for the non-beneficial criteria, is performed.

$$r_{ij} = (x_{ij} - x_j^{min}) / (x_j^{max} - x_j^{min}) \dots\dots j=1,2,\dots,n \quad (2)$$

$$r_{ij} = (x_j^{max} - x_{ij}) / (x_j^{max} - x_j^{min}) \dots\dots j=1,2,\dots,n \quad (3)$$

Stage-3: Correlation coefficient matrix is created to include linear correlation coefficients (p) to measure the degree of relations between the evaluation criteria used during the analysis. The correlation coefficients between the criteria are calculated by using the equation (4).

$$\rho_{jk} = \frac{\sum_{i=1}^{m}(r_{ij}-\bar{r_j})*(r_{ik}-\bar{r_k})}{\sqrt{\sum_{i=1}^{m}(r_{ij}-\bar{r_j})^2 * \sum_{i=1}^{m}(r_{ik}-\bar{r_k})^2}} \qquad j, k = 1,2,\dots,n \quad (4)$$

Stage-4: C_j coefficient, which includes the relationship between the selected evaluation criteria and the contrast intensity information between the alternatives, is calculated. In order to obtain the C_j coefficient, the standard deviations of the criteria in the normalized decision

matrix are calculated by using the equation (5). Afterwards, the coefficient of C_j is obtained by using the equation (6).

$$\sigma_j = \sqrt{\frac{\sum_{i=1}^{m}(r_{ij}-\bar{r}_j)^2}{m-1}} \tag{5}$$

$$C_j = \sigma_j * \sum_{k=1}^{n}(1-\rho_{jk}) \qquad j = 1,2,\ldots,n \tag{6}$$

Stage-5: Weights of the evaluation criteria (w_j) are obtained by equation (7).

$$w_j = \frac{c_j}{\sum_{k=1}^{n} c_j} \tag{7}$$

3. VIKOR Method

The VIKOR (Vise Kriterijumska Optimizacija I Kompromisno Resenje) method is used to order the evaluation criteria, namely the alternatives. In this method, the consensus rankings are decided by taking into account the consensus ranking list, and the weighted decision intervals for the preference decision of the compromise solution are determined with the weights used. The term consensus used in the method means reaching a consensus on an alternative. The stages of the VIKOR method are given below (Opricovic and Tzeng, 2007: 515):

Stage-1: Decision matrix is created, the rows of which show the alternatives (i=1,2,…….,m), the columns the criteria (j=1,2,…….,n). The decision matrix is given in the equation (8).

$$X = \begin{bmatrix} x_{11} & x_{12} & \ldots & x_{1n} \\ x_{21} & x_{22} & \ldots & x_{2n} \\ \vdots & \vdots & \ldots & \vdots \\ x_{m1} & x_{m2} & \ldots & x_{mn} \end{bmatrix} \tag{8}$$

Stage-2: The best (f_i^*) and worst (f_i^-) values are calculated for each of the selected evaluation criteria. During this calculation, the criteria properties are important. Equations (9) are used if the criteria are beneficial, and (10) if they are non-beneficial.

$$\begin{aligned} f_i^* &= \max_i x_{ij} \\ f_i^- &= \min_i x_{ij} \end{aligned} \tag{9}$$

$$\begin{aligned} f_i^* &= \min_i x_{ij} \\ f_i^- &= \max_i x_{ij} \end{aligned} \tag{10}$$

Stage-3: S_j and R_j values of each alternative are calculated using the equations (11) and (12). These values represent the distance of the j^{th} alternative from the best and worst solutions.

$$S_j = \sum_{i=1}^{n} w_i (f_i^* - f_{ij}) / f_i^* - f_i^- \qquad j = 1,2,\ldots,m \tag{11}$$

$$j = \max (w_i (f_i^* - f_{ij}) / (f_i^* - f_i^-)) \tag{12}$$

Stage-4: Q_j values of all alternatives used in the study are calculated by equation (13).

$$Q_j = \upsilon (S_j - S^*) / (S^- - S^*) + (1- \upsilon) (R_j - R^*) / (R^- - R^*) \tag{13}$$

In the above equation:

$$S^* = \min_j S_j \qquad S^- = \max_j S_j$$
$$R^* = \min_j R_j \qquad R^- = \max_j R_j$$

υ: The weight of the strategy for maximum group benefit

In practice, the υ value is usually chosen as 0.5. In this case, the assumption is made that the evaluation expert groups exhibit a conciliatory attitude. If this value is greater than 0.5, it is assumed that the majority has a positive attitude tendency, and if it is small, the majority has a negative attitude tendency (Wei & Lin, 2008: 2).

Stage-5: Obtained Q_j values are sorted. As a result of the ranking, the alternative with the smallest Q_j value is evaluated as the best option.

Stage-6: In order for the results obtained according to the VIKOR method to be valid, two conditions must be met. So, it should be analyzed whether these conditions are met at the last stage of the method. If both conditions are met, it can be concluded that the alternative with the lowest Q value is the best alternative.

Condition-1: Acceptable Advantage

As a first condition, the existence of a significant difference between the best and the closest option is proved. In order for the results obtained as a result of the application of the method to satisfy this condition, the equation numbered (14) must be fulfilled.

$$Q_2 - Q_1 \geq DQ$$
$$DQ = 1/(j-1) \tag{14}$$

Q_1: Q value of the first alternative in the ranking formed as a result of the application

Q_2: Q value of the alternative that is in the second place in the ranking formed as a result of the application

j: Number of the alternatives

Condition-2: Acceptable Stability

It is the condition that must be met to prove that the consensus solution reached as a result of the application of the VIKOR method is stable. At least one of the S and R values of the alternative with the best Q value must also have the best value.

4. Entropy Method

Entropy method is one of the methods used to objectively calculate the weights of the evaluation criteria in MCDM problems (Chen et al., 2015: 91). The implementation of this method is realized by applying the five stages detailed below (Shannon, 1948):

Stage-1: Creation of the decision matrix.

Stage-2: Normalized decision matrix is calculated using the equation (15) below.

$$NS_{ij} = (x_{ij} / \sum_{i=1}^{m} x_{ij}); \forall_j \quad (15)$$

i: Alternative value

j: Criteria value

NS_{ij}: Normalized value

Stage-3: Calculation of entropy values using the equation (16).

$$e_{ij} = -k\sum_{j=1}^{n} x_{ij}.\ln(x_j) \quad (i=1,\ldots,m; \quad j=1,\ldots,n) \quad (16)$$

k: Entropy coefficient $((\ln(n))^{-1}$

NS_{ij}: Normalized value

e_{ij}: Entropy value

Stage-4: Calculating degrees of differentiation (d_j) with the help of equation (17) below.

$$d_j = 1\text{-}E_j, \forall_j \quad (17)$$

Stage-5: Criteria weights (w_j) are calculated using the equation (18).

$$w_j = (d_j / \sum_{j=1}^{n} j_i), \forall_j \qquad \sum_{j=1}^{n} W_j = 1 \qquad 0 \leq W_j \leq 1 \quad (18)$$

5. TOPSIS Method

It is based on the determination of the best alternative over an agreed solution. In this approach, the positive ideal solution is the one that maximizes the benefit criterion and minimizes the cost criterion. The negative ideal solution makes the benefit criterion minimum and the cost criterion maximum. Thus, the solution is the shortest distance from the positive

ideal solution as Euclidean distance or the longest distance from the negative ideal solution as Euclidean distance (Tzeng and Huang, 2011: 69). The stages of the VIKOR method are given below (Olson, 2004: 722; Roszkowska, 2011: 205):

Stage-1: For alternative m numbered (A), n numbered performance criteria (C) are determined. Thus, the matrix $X^k=(x_{ij}^k)$ is obtained.

	C_1	C_2	…	C_n
A_1	x^k_{11}	x^k_{12}	…	x^k_{1n}
A_2	x^k_{21}	x^k_{22}	…	x^k_{2n}
…	…	…	…	…
A_n	x^k_{m1}	x^k_{m2}	…	x^k_{mn}

(19)

The raw data needs to be standardized by dividing each value in the decision matrix by the square root of the sum of the squares of the values of the same criterion.

$$n_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \tag{20}$$

Stage-2: Criterion weights (w) are determined. The normalized matrix is multiplied by the vector created with these weights and $v_{ij}=w_j n_{ij}$ is obtained.

Stage-3: The ideal alternative (best performance on each criterion, A+) and the lowest alternative (extreme performance against each criterion, A-) are determined.

Stage-4: Distance measurements are determined for each.

$$d_i^+ = \sqrt{\sum_{j=1}^{n}(v_{ij} - v_j^+)^2}$$

$$d_i^- = \sqrt{\sum_{j=1}^{n}(v_{ij} - v_j^-)^2} \tag{21}$$

Stage-5: For each alternative, a ratio is calculated by dividing the distance from the lowest alternative by the sum of the distances from both alternatives.

$$R_i = \frac{d_i^-}{d_i^- + d_i^+} \tag{22}$$

The order is made starting from the highest number among the calculated ratios.

6. Z-Score Calculation

In the analyzes performed using MCDM methods, the problem of negative values of the evaluation criteria used may be encountered. Especially in studies involving financial

performance evaluations, some financial ratios may take negative values in certain periods. In such a case, negative values are converted to positive values in practice and analyzes are made after this stage. One of the commonly used methods for converting negative data into positive is the z-score calculation method. Its main stages are given below (Zhang et al., 2014: 3):

Stage-1: Data in the decision matrix is transformed by the following equation.

$$z_{ij} = (x_{ij} - \bar{x}) / \sigma_j \tag{23}$$

Stage-2: With the help of the equation below, the conversion of negative data into positive is carried out.

$$z_{ij}' = z_{ij} + A; \text{ where } A > |\min z_{ij}| \tag{24}$$

7. Literature Review

The scope of the literature review presented in Table 1 is limited to similar studies, which analyze the manufacturing sector or its sub-sectors with MCDM techniques.

Table 1
Literature Review

Study	Model	Variables	Results
Alvandi et al. (2013)	Financial performance rankings of companies operating in auto and spare parts industry are modeled by Fuzzy AHP and VIKOR.	Valued financial performance and accounting financial performance indicators are used.	Rankings are obtained.
Shaverdi et al. (2014)	Financial performance assessment of petrochemical industry companies is modeled by Fuzzy AHP.	Liquidity ratios (2), financial leverage ratios (4), activity ratios (4), profitability ratios (3), growth ratios (4)	Rankings are obtained.
Karakış & Göktolga (2015)	Financial performances of automotive manufacturing companies registered in BIST are modeled for the period 2010-2014 by AHP and ELECTRE methods.	Nine ratios are used.	No significant deviation in rankings.
Akbulut & Rençber (2015)	Financial performances of the manufacturing companies registered in BIST are modeled for the period 2010-2012 by weighed average and TOPSIS.	Liquidity ratios (3), activity ratios (3), profitability ratios (4)	No significant relation between TOPSIS results and market performances.
Farrokh et al. (2016)	Financial performances of basic metal companies in Iran are evaluated with Fuzzy AHP, VIKOR and TOPSIS.	Liquidity ratios (2), financial leverage ratios (4), profitability ratios (2), growth ratios (4)	Rankings are obtained.
Alimohammadlou (2017)	Financial performances of companies operating in food industry in Iran are modeled for 2011-2015 period by BWM and Promethee II.	Profitability ratio (1), activity ratio (1), liquidity ratio (1), financial structure ratios (2)	Rankings are obtained.
Yanık & Eren (2017)	Financial performances of the automotive manufacturing companies listed in BIST-100 index are modeled for 2011-2015 by AHP, TOPSIS, VIKOR, Electre.	Eight ratios are used.	Similar results are obtained.

Karadeniz et.al (2017)	Financial performances of the manufacturing sub-sectors are modeled for 2012-2014 by GRA.	Liquidity ratios (3), financial structure ratios (12), asset usage ratios (6), profitability ratios (11)	Rankings are obtained.
Eyüboğlu & Bayraktar (2018)	Financial performances of the manufacturing companies are modeled for 2014-2016 by using AHP and TOPSIS.	Liquidity ratios (4), activity ratios (5), financial structure ratios (4), profitability ratios (6)	Small and medium-scale company performances are weak.
Apan & Öztel (2018)	Scale-based financial performances of the manufacturing companies are modeled for 2004-2014 by Promethee method. Entropy, CRITIC, standard deviation and mean weighting are used to determine weights.	Fifteen ratios are used.	Different results are obtained.
Anthony et al. (2019)	Financial performance of chemical companies in India are modeled for -2018 by TOPSIS, COPRAS, Entropy and DEA.	Financial ratios are used.	Different results are obtained.
Çanakçıoğlu (2019)	Financial performances of the chemical, petroleum, rubber, and plastics manufacturing companies listed in BIST are modeled for 2013-2017 by using Entropy and GRA.	Financial structure ratios (2), activity ratios (4), profitability ratios (4)	Unstable performances are reported.
Şahin & Sarı (2019)	Financial performances of the manufacturing companies registered in BIST are modeled for 2013-2016 by Entropy, TOPSIS, and VIKOR.	Five ratios are used.	No significant relation between model results and market performances.
Rençber (2019)	Financial performances of the manufacturing companies registered in BIST with the highest 30 and lowest 30 in ROA are modeled and categorized for 2017 by GRA and VIKOR.	Four ratios are used.	GRA results are more significant comparing VIKOR results.
Abdel-Basset et al. (2020)	Financial performance of steel company in Egypt are analyzed using AHP, VIKOR and TOPSIS.	Four financial ratios and twenty sub-criteria are used.	Different results are obtained.
Ban, et al. (2020)	Financial performance of manufacturing companies in Iran for 2011-2015 period are modeled with Fuzzy AHP and TOPSIS.	Financial and non-financial indicators are used.	Non-financial indicators have effect on performance.
Yürük & Orhan (2020)	Financial performances of the manufacturing sub-sectors are modeled for 2006-2017 by Entropy, Critic, and MAUT.	Six ratios are used.	Manufacturing of chemicals and chemical products sector is emphasized.
Çokmutlu & Kılıç (2020)	Financial performances of the manufacturing companies listed in the BIST sustainability index are modeled for 2015-2017 by using Entropy and TOPSIS.	Liquidity ratios (3), activity ratios (7), financial structure ratios (7), profitability ratios (5), growth ratios (4), market-based ratios (5)	Economic, social, environmental, and total sustainability performances are not fully reflected in financial performance.
Gök Kısa & Perçin (2020)	Financial performances of the manufacturing companies registered in BIST index are modeled by Fuzzy AHP, TOPSIS, VIKOR, GRA.	Liquidity ratios (3), activity ratios (5), financial leverage ratios (5), profitability ratios (4), growth ratios (3)	Similar results are obtained.
Açıkgöz (2021a)	Financial performances of the cash flow profiles obtained from manufacturing companies registered in BIST are modeled for 2015-2019 by TOPSIS.	Seven ratios are used.	Rankings are obtained.

Özkan & Ağ (2021)	Corporate sustainability performances of the manufacturing companies registered in BIST are modeled for 2016 by Critic based ARAS.	Economic ratios (7), environmental ratios (6), social ratios (5)	Rankings are obtained.
Açıkgöz (2021b)	Financial performances of the manufacturing companies compliant with corporate management principles are modeled for 2010-2013 by TOPSIS.	Liquidity ratios (2), activity ratios (3), financial structure ratios (4), profitability ratios (5), growth ratios (4) with equal weights.	Companies compliant with corporate governance principles have better performance.

This study differs from other studies in the literature in that it uses the CRITIC based VIKOR method. Another contribution of the study is that this is one of the few studies comparing profitability performances of the manufacturing sub-sectors by using different MCDM methods.

8. Profitability Performance Analysis of BIST Manufacturing Sub-sectors

8.1. Objective

The objective of the study is determining the profitability performances of the sub-sectors of the BIST manufacturing sector for the period 2019-2021 using different MCDM methods for weighting and ranking and to make financial analyzes with the help of the financial ratios used.

8.2. Scope

The scope of this study consists of the sub-sectors of the BIST manufacturing sector. There are 190 companies in 9 sub-sectors in the BIST manufacturing sector. Information on the mentioned sub-sectors and the number of companies is given in Table 2.

Table 2
BIST Manufacturing Sub-Sectors and Number of Businesses

#	Sub-Sector	Number of Businesses
1	Food, Beverage and Tobacco	32
2	Textile, Wearing Apparel and Leather	24
3	Wood Products Including Furniture	6
4	Paper and Paper Products, Printing and Publishing	15
5	Chemicals, Petroleum Rubber and Plastic Products	37
6	Non-Metallic Mineral Products	22
7	Basic Metal	21
8	Fabricated Metal Products, Machinery, Electrical Equipment and Transportation Vehicles	32
9	Other Manufacturing Industry	1
	Total	**190**

Considering the number of enterprises in the sub-sectors in the table above, Wood Products Including Furniture and Other Manufacturing Industry sub-sectors are not included in the scope. The profitability performances of the remaining 7 sub-sectors for the period 2019-

2021 are taken as the sample set. 7 sub-sectors in question constitute the alternatives of the study.

8.3. Method

Four different MCDM methods are used in the study. CRITIC based VIKOR, Entropy based TOPSIS, CRITIC based TOPSIS and Entropy based VIKOR methods are choosen. In order to evaluate the profitability performances of the selected sub-sectors, 6 evaluation criteria consisting of financial ratios are determined. For each evaluation criteria, the average value of all enterprises operating in the relevant sub-sector is calculated and the average value of the relevant sub-sector is obtained for each criterion. All analyzes are carried out using sub-sector average values.

8.4. Analysis

In the study, the sub-sectors included in the scope of the study are determined and a code is given to each sub-sector. As stated in the previous sections, 7 sub-sectors are included as alternatives to the study. Information on the selected alternatives and their codes are presented in Table 3.

Table 3
Alternatives and Their Codes

Code	Sub-Sector
A-1	Basic Metal
A-2	Paper and Paper Products, Printing and Publishing
A-3	Chemicals, Petroleum Rubber and Plastic Products
A-4	Fabricated Metal Products, Machinery, Electrical Equipment and Transportation Vehicles
A-5	Non-Metallic Mineral Products
A-6	Textile, Wearing Apparel and Leather
A-7	Food, Beverage and Tobacco

In order to evaluate the profitability performances of the sub-sectors included in the study, 6 financial ratios are determined as evaluation criteria. Later on, the determined criteria are grouped according to their objective functions. The financial ratios and objective functions used as evaluation criteria in the study are given in Table 4 below.

Table 4
Evaluation Criteria and Objective Functions

Code	Evaluation Criteria	Objective Function
C-1	Return on Asset (%)	Beneficial
C-2	Return on Equity (%)	Beneficial
C-3	Net Profit Margin (%)	Beneficial
C-4	Gross Profit Margin (%)	Beneficial
C-5	Operating Profit Margin (%)	Beneficial
C-6	Cost of Sales/ Total Revenue (%)	Non-beneficial

The analysis part of the study consists of three stages. In the first stage, the weights of the selected evaluation criteria for each year of the 2019-2021 period are determined using the CRITIC and Entropy methods. Then, the calculated weights are used as input in the VIKOR and TOPSIS methods, and by applying these methods, the alternatives are ranked for the specified years. In the last part, comments are made on the results obtained.

Original data for 2021, 2020 and 2019 financial ratios for the selected manufacturing sub-sectors are presented in Appendix. In addition, as can be seen from the data in Appendix, some financial ratios in 2020 and 2019 have negative values for some sub-sectors. For this reason, while preparing the decision matrices for the years 2020 and 2019, these negative values are converted to positive by means of the z-score calculation method, whose stages are explained in the previous sections. Analyzes are carried out using the corrected decision matrices obtained as a result of using this method. Since there are no negative values in the 2021 financial ratios of the sub-sectors, the z-score method is not used for 2021.

8.4.1. CRITIC Based VIKOR Method

At this stage of the study, the weights of the evaluation criteria for 2019, 2020, and 2021 are calculated using the CRITIC method. In this section, only the details of the calculations for the year 2021 are given, the calculations for the other years are carried out by following the same steps and only the final results are presented.

At the stage of determining the criteria weights for 2021, first of all, as stated in the equation (1), the decision matrix containing the values taken by the evaluation criteria and the details of which are given in Table 5 is created.

Table 5
Decision Matrix

Alternatives/ Criteria	C-1	C-2	C-3	C-4	C-5	C-6
A-1	13.30	31.82	10.09	20.29	17.21	79.71
A-2	13.39	32.16	14.44	21.78	9.98	78.22
A-3	14.99	32.07	15.75	27.94	17.27	72.06
A-4	12.56	28.70	9.81	23.79	15.96	76.26
A-5	7.47	18.96	13.28	21.11	9.01	78.89
A-6	9.46	20.08	14.15	31.81	19.94	69.39
A-7	7.87	14.69	10.08	20.64	11.65	79.39

Afterwards, the normalization of the decision matrix is carried out with equations (2) and (3), taking into consideration the objective functions of the evaluation criteria. The normalized decision matrix is given in Table 6.

Table 6
Normalized Decision Matrix

Criteria	**C-1**	**C-2**	**C-3**	**C-4**	**C-5**	**C-6**
Alternatives/ Objective Functions	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Non-beneficial
A-1	0.7753	0.9805	0.0471	0.0000	0.7502	0.0000
A-2	0.7872	1.0000	0.7795	0.1293	0.0887	0.1444
A-3	1.0000	0.9948	1.0000	0.6641	0.7557	0.7413
A-4	0.6769	0.8019	0.0000	0.3038	0.6359	0.3343
A-5	0.0000	0.2444	0.5842	0.0712	0.0000	0.0795
A-6	0.2646	0.3085	0.7306	1.0000	1.0000	1.0000
A-7	0.0532	0.0000	0.0455	0.0304	0.2415	0.0310

In the following stage, the correlation coefficient matrix is obtained based on the equation (4) and the linear correlation coefficients (p_{ij}) between the evaluation criteria are calculated. The correlation coefficient matrix, which includes the linear relationship coefficients, is given in Table 7.

Table 7
Correlation Coefficient Matrix

Criteria	**C-1**	**C-2**	**C-3**	**C-4**	**C-5**	**C-6**
C-1	1.0000	0.9611	0.2290	0.1332	0.3842	0.1758
C-2	0.9611	1.0000	0.2063	-0.0007	0.2539	0.0367
C-3	0.2290	0.2063	1.0000	0.5676	0.0221	0.5872
C-4	0.1332	-0.0007	0.5676	1.0000	0.7133	0.9977
C-5	0.3842	0.2539	0.0221	0.7133	1.0000	0.7097
C-6	0.1758	0.0367	0.5872	0.9977	0.7097	1.0000

In the next step, the C_j coefficients, which include the relationship between the selected evaluation criteria and the contrast density between the alternatives, are calculated by equations (5) and (6). The obtained results are given in Table 8.

Table 8
C_j Coefficients

Criteria	**C-1**	**C-2**	**C-3**	**C-4**	**C-5**	**C-6**
C_j	1.2363	1.4964	1.4077	0.9832	1.1185	0.9727

At the last stage, the weights of the evaluation criteria for 2021 are calculated with the help of equation (7) and the results in Table 9 are obtained.

Table 9
Weights of Evaluation Criteria

Criteria	**C-1**	**C-2**	**C-3**	**C-4**	**C-5**	**C-6**
w_j	0.1714	0.2074	0.1951	0.1363	0.1550	0.1348

All of the above-mentioned stages are applied in the same way for the years 2020 and 2019. As a result, the weights of the evaluation criteria reached for all years are given in Table 10 below.

Table 10
Weights of Evaluation Criteria for the 2019-2021 Period

Criteria/ Year	C-1	C-2	C-3	C-4	C-5	C-6
2021	0.1714	0.2074	0.1951	0.1363	0.1550	0.1348
2020	0.1388	0.1828	0.1287	0.2260	0.1201	0.2035
2019	0.1336	0.1814	0.1309	0.1877	0.1917	0.1747

Based on the data in Table 10, the most important criteria for 2021 is return on equity, the least important criterion is the cost of sales/ total revenue. While the most important criterion for 2020 is the gross profit margin, the least important criterion is the operating profit margin. For 2019, the most important criterion stands out as the operating profit margin, while the least important criterion is the net profit margin.

Following the calculation of the weights of the evaluation criteria with the CRITIC method, the rankings of the alternatives are obtained using the VIKOR method. While applying this method, as in the CRITIC method, only the details of the calculations for the year 2021 are explained, and the calculations for the other years are carried out by following the same steps and only the results are presented.

The primary step of the VIKOR method is the creation of a decision matrix. As explained in previous parts, 7 alternatives and 6 evaluation criteria are determined and the decision matrix given in Table 11 is reached with the help of equation (8).

Table 11
Decision Matrix

Alternatives/ Criteria	C-1	C-2	C-3	C-4	C-5	C-6
A-1	13.30	31.82	10.09	20.29	17.21	79.71
A-2	13.39	32.16	14.44	21.78	9.98	78.22
A-3	14.99	32.07	15.75	27.94	17.27	72.06
A-4	12.56	28.70	9.81	23.79	15.96	76.26
A-5	7.47	18.96	13.28	21.11	9.01	78.89
A-6	9.46	20.08	14.15	31.81	19.94	69.39
A-7	7.87	14.69	10.08	20.64	11.65	79.39

In the next step, the best and worst values are calculated based on the equations (9) and (10), considering their benefit or cost orientation (objective functions) for each of the selected evaluation criteria. The results obtained are given in Table 12.

Table 12
Best and Worst Values

Criteria	**C-1**	**C-2**	**C-3**	**C-4**	**C-5**	**C-6**
Alternatives/ Objective Functions	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Non-beneficial
A-1	13.30	31.82	10.09	20.29	17.21	79.71
A-2	13.39	32.16	14.44	21.78	9.98	78.22
A-3	14.99	32.07	15.75	27.94	17.27	72.06
A-4	12.56	28.70	9.81	23.79	15.96	76.26
A-5	7.47	18.96	13.28	21.11	9.01	78.89
A-6	9.46	20.08	14.15	31.81	19.94	69.39
A-7	7.87	14.69	10.08	20.64	11.65	79.39
Best	14.99	32.16	15.75	31.81	19.94	69.39
Worst	7.47	14.69	9.81	20.29	9.01	79.71

In the following stage, using the weights obtained as a result of the CRITIC method, S_j and R_j values are calculated by equations (11) and (12). The results obtained are given in Table 13.

Table 13
S_j and R_j Values

Weights	0.1714	0.2074	0.1951	0.1363	0.1550	0.1348	**S_j and R_j Values**	
Alternatives/ Criteria	**C-1**	**C-2**	**C-3**	**C-4**	**C-5**	**C-6**	**Sj**	**Rj**
A-1	0.04	0.00	0.19	0.14	0.04	0.13	0.54	0.19
A-2	0.04	0.00	0.04	0.12	0.14	0.12	0.45	0.14
A-3	0.00	0.00	0.00	0.05	0.04	0.03	0.12	0.05
A-4	0.06	0.04	0.20	0.09	0.06	0.09	0.53	0.20
A-5	0.17	0.16	0.08	0.13	0.16	0.12	0.81	0.17
A-6	0.13	0.14	0.05	0.00	0.00	0.00	0.32	0.14
A-7	0.16	0.21	0.19	0.13	0.12	0.13	0.94	0.21

In the next step, the Q_j values of all the alternatives used in the study are calculated using the equation (13) and the rankings of the alternatives are made based on the results. In the calculation, the υ value is accepted as 0.5, as it is mainly chosen in this way in practice, based on the assumption that the evaluation expert groups exhibited a conciliatory attitude. The Q_j values obtained and the rankings made within this framework are given in Table 14.

Table 14
Rankings of Alternatives

Alternatives	**Qj**	**Ranking**
A-1	0.69	4
A-2	0.50	3
A-3	0.00	1
A-4	0.71	5
A-5	0.81	6
A-6	0.43	2
A-7	1.00	7

All of the above-mentioned stages are applied in the same way for 2020 and 2019. The rankings of the alternatives reached for all years are given in Table15 below.

Table 15
Ranking Results

Alternatives	2019	2020	2021
A-1	6	6	4
A-2	5	5	3
A-3	1	1	1
A-4	4	2	5
A-5	7	7	6
A-6	3	4	2
A-7	2	3	7

Following the achievement of the results given in Table 15 for the 2019-2021 period, in order to confirm the validity of these results, as a requirement of the VIKOR method, at the last stage of the study, it is tested whether acceptable advantage and acceptable stability conditions are provided for all three years.

First, the acceptable advantage condition is tested. The fulfillment of this condition is possible with the realization of the Q_2-$Q_1 \geq DQ$ inequality. Information on whether the condition is fulfilled for the years included in the study is given in Table 16 below. As can be seen from the data, an acceptable advantage condition is provided for all years.

Table 16
Acceptable Advantage Condition Test

Year	Q_2	Q_1	DQ=(1/j-1)	Q_2- $Q_1 \geq DQ$	Condition Fulfillment
2021	0.43	0.00	0.167	0.43-0.00>0.167	✓
2020	0.30	0.00	0.167	0.30-0.00>0.167	✓
2019	0.38	0.00	0.167	0.38-0.00>0.167	✓

Second, the acceptable stability condition is tested. In order to satisfy this condition, the alternative with the best Q value must also have the best value, at least one of the S and R values. Information on whether the condition is fulfilled for the years included in the study is given in Table17 below. The results show that this condition is also fulfilled.

Table 17
Acceptable Stability Condition Test

Year	S Value of Alternative with Best Q Value	R Value of Alternative with Best Q Value	Best S Value	Best R Value	Condition Fulfillment
2021	0.12	0.05	0.12	0.05	✓
2020	0.00	0.00	0.00	0.00	✓
2019	0.00	0.00	0.00	0.00	✓

Providing acceptable advantage and acceptable stability conditions shows that the results of this study are valid. After the results are evaluated based on the validity conditions, it is determined that the Chemicals, Petroleum Rubber and Plastic Products sub-sector shows the highest profitability performance for all three years. The lowest performance is the Food, Beverage and Tobacco sub-sector in 2021, and the Non-Metallic Mineral Products in 2020 and 2019.

8.4.2. Entropy Based TOPSIS Method

In this sub-section, the weights of the evaluation criteria for 2019, 2020, and 2021 are calculated using the Entropy method. As mentioned in the previous sections, only the details of the calculations for the year 2021 are given, the calculations for the other years are carried out by following the same steps and only the final results are presented.

First, the decision matrix is created for 2021 as shown in Table 18 below.

Table 18
Decision Matrix

Alternatives/ Criteria	**C-1**	**C-2**	**C-3**	**C-4**	**C-5**	**C-6**
A-1	13.30	31.82	10.09	20.29	17.21	79.71
A-2	13.39	32.16	14.44	21.78	9.98	78.22
A-3	14.99	32.07	15.75	27.94	17.27	72.06
A-4	12.56	28.70	9.81	23.79	15.96	76.26
A-5	7.47	18.96	13.28	21.11	9.01	78.89
A-6	9.46	20.08	14.15	31.81	19.94	69.39
A-7	7.87	14.69	10.08	20.64	11.65	79.39

As second stage of the Entropy method, normalized decision matrix is prepared using equation (15). Normalized decision matrix is presented in Table 19.

Table 19
Normalized Decision Matrix

Criteria	**C-1**	**C-2**	**C-3**	**C-4**	**C-5**	**C-6**
Alternatives/ Objective Functions	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Non-beneficial
A-1	0.1683	0.1783	0.1152	0.1212	0.1704	0.1493
A-2	0.1694	0.1802	0.1648	0.1301	0.0988	0.1465
A-3	0.1897	0.1797	0.1798	0.1669	0.1710	0.1350
A-4	0.1589	0.1608	0.1120	0.1421	0.1580	0.1428
A-5	0.0945	0.1062	0.1516	0.1261	0.0892	0.1478
A-6	0.1197	0.1125	0.1615	0.1901	0.1974	0.1300
A-7	0.0996	0.0823	0.1151	0.1233	0.1153	0.1487

After the preparation of the normalized matrix, with the help of equation (16) entropy values are calculated as shown in Table 20.

Table 20
Entropy Values

Criteria	C-1	C-2	C-3	C-4	C-5	C-6
Alternatives/ Objective Functions	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Non-beneficial
A-1	-0.2999	-0.3074	-0.2489	-0.2558	-0.3015	-0.2839
A-2	-0.3008	-0.3088	-0.2972	-0.2654	-0.2287	-0.2814
A-3	-0.3153	-0.3084	-0.3085	-0.2988	-0.3020	-0.2703
A-4	-0.2923	-0.2939	-0.2452	-0.2773	-0.2915	-0.2780
A-5	-0.2230	-0.2382	-0.2860	-0.2612	-0.2156	-0.2825
A-6	-0.2541	-0.2458	-0.2945	-0.3156	-0.3203	-0.2652
A-7	-0.2297	-0.2055	-0.2488	-0.2581	-0.2491	-0.2834

With the help of equation (17), degrees of differentiation are calculated as presented in Table 21 below.

Table 21
Differentiation Degrees

C-1	C-2	C-3	C-4	C-5	C-6
0.3241	0.3265	0.3191	0.3180	0.3263	0.3136

In the last stage below criteria weights are obtained by using equation (18).

Table 22
Criteria Weights

C-1	C-2	C-3	C-4	C-5	C-6
0.1681	0.1694	0.1655	0.1650	0.1693	0.1627

All of the above-mentioned stages are applied in the same way for the years 2020 and 2019. As a result, the weights of the evaluation criteria reached with the Entropy method for all three years are given in Table 23 below.

Table 23
Weights of Evaluation Criteria

Criteria/ Year	C-1	C-2	C-3	C-4	C-5	C-6
2021	0.1681	0.1694	0.1655	0.1650	0.1693	0.1627
2020	0.1774	0.1677	0.2012	0.1466	0.1636	0.1434
2019	0.1923	0.1866	0.1905	0.1356	0.1619	0.1331

Based on the data in Table 23, the most important criteria for 2021 is return on equity, the least important criterion is the cost of sales/ total revenue. While the most important criterion for 2020 is the net profit margin, the least important criterion is the cost of sales/ total revenue. For 2019, the most important criterion stands out as the return on asset, while the least important criterion is the cost of sales/ total revenue.

In the first step of the TOPSIS methodology, n_{ij} matrix is obtained. For 2021 data, n_{ij} matrix calculated as depicted in Table 24.

Table 24
n_{ij} Matrix

Alternatives/Criteria	C-1	C-2	C-3	C-4	C-5	C-6
A-1	0.4325	0.4556	0.2998	0.3163	0.4353	0.3945
A-2	0.4354	0.4605	0.4290	0.3395	0.2524	0.3871
A-3	0.4874	0.4592	0.4680	0.4355	0.4368	0.3567
A-4	0.4084	0.4109	0.2915	0.3708	0.4037	0.3774
A-5	0.2429	0.2715	0.3946	0.3290	0.2279	0.3905
A-6	0.3076	0.2875	0.4204	0.4958	0.5043	0.3434
A-7	0.2559	0.2103	0.2995	0.3217	0.2947	0.3929

By using weights calculated after the entropy process, in the second step, the following matrix shown in Table 25 as v_{ij} matrix will be obtained.

Table 25
v_{ij} Matrix

Alternatives/Criteria	C-1	C-2	C-3	C-4	C-5	C-6
A-1	0.0727	0.0772	0.0496	0.0522	0.0737	0.0642
A-2	0.0732	0.0780	0.0710	0.0560	0.0427	0.0630
A-3	0.0819	0.0778	0.0775	0.0718	0.0739	0.0580
A-4	0.0687	0.0696	0.0483	0.0612	0.0683	0.0614
A-5	0.0408	0.0460	0.0653	0.0543	0.0386	0.0635
A-6	0.0517	0.0487	0.0696	0.0818	0.0854	0.0559
A-7	0.0430	0.0356	0.0496	0.0531	0.0499	0.0639

By using alternatives, distance measurements d_i^+ and d_i^- are calculated as represented in Table 26.

Table 26
d_i^+ and d_i^- values

Alternatives/ Criteria	C-1		C-2		C-3		C-4		C-5		C-6	
	d_i^+	d_i^-	d_i^+	d_i^-	d_i^+	d_i^-	d_i^+	d_i^-	d_i^+	d_i^-	d_i^+	d_i^-
A-1	0.0001	0.0010	0.0000	0.0017	0.0008	0.0000	0.0009	0.0000	0.0001	0.0012	0.0001	0.00000
A-2	0.0001	0.0010	0.0000	0.0018	0.0000	0.0005	0.0007	0.0000	0.0018	0.0000	0.0001	0.00000
A-3	0.0000	0.0017	0.0000	0.0018	0.0000	0.0009	0.0001	0.0004	0.0001	0.0013	0.0000	0.00004
A-4	0.0002	0.0008	0.0001	0.0012	0.0009	0.0000	0.0004	0.0001	0.0003	0.0009	0.0000	0.00001
A-5	0.0017	0.0000	0.0010	0.0001	0.0001	0.0003	0.0008	0.0000	0.0022	0.0000	0.0001	0.00000
A-6	0.0009	0.0001	0.0009	0.0002	0.0001	0.0005	0.0000	0.0009	0.0000	0.0022	0.0000	0.00007
A-7	0.0015	0.0000	0.0018	0.0000	0.0008	0.0000	0.0008	0.0000	0.0013	0.0001	0.0001	0.00000

R_i is calculated as distance measurements as shown in Table 27.

Table 27
R_i values

Alternatives	R_i
A-1	0.5885
A-2	0.5308
A-3	0.8349
A-4	0.5563
A-5	0.2077
A-6	0.5926
A-7	0.1283

The same process can be applied for the other years. Table 28 is obtained by the Entropy based TOPSIS method.

Table 28
Ranking Results

Alternatives	2019	2020	2021
A-1	5	4	3
A-2	6	6	5
A-3	1	1	1
A-4	3	2	4
A-5	7	7	6
A-6	4	5	2
A-7	2	3	7

According to the results of the Entropy based TOPSIS method Chemicals, Petroleum Rubber and Plastic Products sub-sector shows the highest profitability performance for all three years. The lowest performance is the Food, Beverage and Tobacco sub-sector in 2021, and the Non-Metallic Mineral Products in 2020 and 2019.

8.4.3. CRITIC Based TOPSIS Method

The use of CRITIC and TOPSIS methods in MCDM problems in the analyzes performed in the sub-headings 8.4.1 and 8.4.2 of the "Analysis" section of the study is indicated by explaining the calculations performed at each stage in detail. For this reason, detailed calculation steps of the CRITIC based TOPSIS method analyzed in this sub-section are not included. Only, the final results obtained are presented below.

Table 29
Ranking Results

Alternatives	2019	2020	2021
A-1	5	4	2
A-2	6	6	3
A-3	1	1	1
A-4	3	2	4
A-5	7	7	6
A-6	4	5	5
A-7	2	3	7

According to the results of the Critic based TOPSIS method Chemicals, Petroleum Rubber and Plastic Products sub-sector shows the highest profitability performance for all three years. The lowest performance is the Food, Beverage and Tobacco sub-sector in 2021, and the Non-Metallic Mineral Products in 2020 and 2019.

8.4.4. Entropy Based VIKOR Method

The use of Entropy and VIKOR methods in MCDM problems in the analyzes performed in the sub-headings 8.4.1 and 8.4.2 of the "Analysis" section of the study is indicated by explaining the calculations performed at each stage in detail. For this reason, only the final results obtained are presented in Table 30.

Table 30
Ranking Results

Alternatives	2019	2020	2021
A-1	5	5	5
A-2	6	6	3
A-3	1	1	1
A-4	4	2	4
A-5	7	7	6
A-6	3	4	2
A-7	2	3	7

Entropy based VIKOR method results indicate that Chemicals, Petroleum Rubber and Plastic Products sub-sector shows the highest profitability performance for all three years. The lowest performance is the Food, Beverage and Tobacco sub-sector in 2021, and the Non-Metallic Mineral Products in 2020 and 2019.

8.4.5. Evaluation of Analysis Results

The final results of the analyzes performed using four different integrated methods are presented comparatively in Tables 31, 32 and 33 for the years 2019, 2020 and 2021.

Based on the data in Table 31 below, it is seen that the first, second and last sub-sectors in terms of profitability performances are the same in the results of four different methods. There are minor differences in other rankings.

Table 31
Ranking Results-2019

Alternatives	CRITIC-VIKOR	Entropy-TOPSIS	CRITIC-TOPSIS	Entropy-VIKOR
A-1	6	5	5	5
A-2	5	6	6	6
A-3	1	1	1	1
A-4	4	3	3	4
A-5	7	7	7	7
A-6	3	4	4	3
A-7	2	2	2	2

Table 32 shows the rankings of the profitability performances of the sub-sectors in 2020 performed by different MCDM methods. In the examination, it is determined that all the

methods applied give the same results for the first, second, third and last sub-sectors. There are minor differences in other rankings.

Table 32
Ranking Results-2020

Alternatives	CRITIC-VIKOR	Entropy-TOPSIS	CRITIC-TOPSIS	Entropy-VIKOR
A-1	6	4	4	5
A-2	5	6	6	6
A-3	1	1	1	1
A-4	2	2	2	2
A-5	7	7	7	7
A-6	4	5	5	4
A-7	3	3	3	3

When the 2021 success rankings in Table 33 below are analyzed, it is concluded that the sub-sectors in the first, sixth and seventh ranks in terms of profitability performances are the same in all methods applied. There are minor differences in other rankings.

Table 33
Ranking Results-2021

Alternatives	CRITIC-VIKOR	Entropy-TOPSIS	CRITIC-TOPSIS	Entropy-VIKOR
A-1	4	3	2	5
A-2	3	5	3	3
A-3	1	1	1	1
A-4	5	4	4	4
A-5	6	6	6	6
A-6	2	2	5	2
A-7	7	7	7	7

The general results obtained as a result of the rankings made with four different integrated MCDM methods for the years 2019, 2020 and 2021 are as follows:

(1) Chemicals, Petroleum Rubber and Plastic Products sub-sector has maintained its position. Regardless of the method selected, this sub-sector holds the first rank during the period.

(2) Textile, Wearing Apparel and Leather sub-sector is negatively affected, but in the second year of the pandemic, it went back to its pre-pandemic position. Critic based TOPSIS method is the only case that this sub-sector cannot be affected positively in the third year comparing the second.

(3) Although Food, Beverage and Tobacco sub-sector is affected only one single rank negatively in the first year, in the second year it lost its position completely and showed the worst performance comparatively. Due to the falling position of the Food, Beverage and Tobacco sub-sector, Paper and Paper Products, Printing and Publishing sub-sector,

Basic Metal sub-sector and Non-metallic Mineral Products sub-sector went up. The only exception for this situation is the Basic Metal sub-sector in Entropy based VIKOR analysis.

(4) Fabricated Metal Products, Machinery, Electrical Equipment and Transportation Vehicles sub-sector is positively affected in the first year, but in 2021 it came back to almost its previous position, or to a worser position from the first year, depending on the technique used in analysis.

Thus, it can be concluded that the most dramatic effect of the covid-19 pandemic on manufacturing sub-sectors' profitability is seen in Food, Beverage and Tobacco sub-sector.

During the financial year 2020, first year of the pandemic, for all sub-sectors, two profit indicators are improved: cost of sales/ total revenues and gross profit margin. Although positive effects seen in these two indicators are different by sub-sectors, all sub-sectors are affected positively in the manner of these two sub-sectors. In the next year, 2021, the same is true for return on equity and return on asset indicators.

Although Chemicals, Petroleum Rubber and Plastic Products sub-sector is not the one that shows better performance in 2020 and 2021 years, since the starting point of its profitability in 2019 is better than other sub-sectors, it achieved to put its position in the first rank in all variables, except return on equity, gross profit margin, operating profit margin and cost of sales/ total revenue margin.

When profitability performance rankings are compared with index price performances of manufacturing sub-sectors, the following comparison tables are obtained. Note that index performances are found by calculating changes in index prices (see appendix for raw data) from one year-end to another. Table 34, 35, 36 present results of different MCDM methods and index price performance rankings of sub-sectors by years.

Table 34
Index Prices and Ranking Results-2019

Alternatives	Index	CRITIC-VIKOR	Entropy-TOPSIS	CRITIC-TOPSIS	Entropy-VIKOR
A-1	6	6	5	5	5
A-2	1	5	6	6	6
A-3	7	1	1	1	1
A-4	3	4	3	3	4
A-5	4	7	7	7	7
A-6	2	3	4	4	3
A-7	5	2	2	2	2

Table 35
Index Prices and Ranking Results-2020

Alternatives	Index	CRITIC-VIKOR	Entropy-TOPSIS	CRITIC-TOPSIS	Entropy-VIKOR
A-1	5	6	4	4	5
A-2	1	5	6	6	6
A-3	6	1	1	1	1
A-4	4	2	2	2	2
A-5	2	7	7	7	7
A-6	3	4	5	5	4
A-7	7	3	3	3	3

Table 36
Index Prices and Ranking Results-2021

Alternatives	Index	CRITIC-VIKOR	Entropy-TOPSIS	CRITIC-TOPSIS	Entropy-VIKOR
A-1	1	4	3	2	5
A-2	7	3	5	3	3
A-3	2	1	1	1	1
A-4	3	5	4	4	4
A-5	6	6	6	6	6
A-6	4	2	2	5	2
A-7	5	7	7	7	7

Spearman's rank correlation test is used to analyze whether there is a relationship between index price and profitability performance rankings for each year on the basis of the MCDM methods used in the sub-sectors included in the study. The obtained results are given in Table 37 below.

Table 37
Spearman's Rank Correlation Coefficients

	2019	2020	2021
Index/CRITIC-VIKOR	-0.2857	-0.57143	0.3214
Index/Entropy-TOPSIS	-0.5000	-0.78571	0.6786
Index/CRITIC-TOPSIS	-0.5000	-0.78571	0.5714
Index/Entropy-VIKOR	-0.4643	-0.71429	0.2500

As can be seen from the Spearman's rank correlation coefficients in Table 37 above, it is identified that there is generally no significant relationship between the index price rankings and profitability performance rankings of the manufacturing sub-sectors on a yearly basis. Only for the year 2021, positive and strong (0.6786) relationship is found between the rankings made with the Entropy-TOPSIS method and the index price rankings.

9. Conclusion

In terms of both our country and other countries' economies, the manufacturing sector is accepted as the engine of economic growth and development. When the growth data of our

country since the 1980s are analyzed, it is seen that the manufacturing sector plays an important role. For this reason, the profitability performances of the manufacturing sector and its sub-sectors are extremely important for policy-makers.

In this study, the objective of which is to examine the profitability performances of the BIST manufacturing sub-sectors for the period 2019-2021, 6 financial ratios are determined as evaluation criteria for the measurement of profitability performance. The sample set of the study consists of 7 sub-sectors of the BIST manufacturing sector. Evaluation criteria are weighted with the CRITIC and the Entropy methods, and the VIKOR and the TOPSIS methods are used for the performance rankings of the sub-sectors for each year. For different combined MCDM methods which are CRITIC based VIKOR, CRITIC based TOPSIS, Entropy based VIKOR and Entropy based TOPSIS are applied to the data set. Also, for the conversion of negative values to positive z-score calculation method is used.

According to the results of the study, Chemicals, Petroleum Rubber and Plastic Products sub-sector ranks the first, while the Food, Beverage and Tobacco sub-sector ranks the last in terms of profitability performance in the analyzes made using four different integrated methods. Chemicals, Petroleum Rubber and Plastic Products sub-sector has maintained its position in the pandemic period. Textile, Wearing Apparel and Leather sub-sector is negatively affected in terms of profitability performance in the first year of the pandemic. Food, Beverage and Tobacco sub-sector is affected only in one ranking negatively in the first year, but in the second year it showed the worst performance comparatively. Fabricated Metal Products, Machinery, Electrical Equipment and Transportation Vehicles sub-sector is positively affected in the first year of the pandemic. In 2021 it came back to almost its previous position, or to a worser position from the first year, depending on the combined MCDM method used in analysis.

In the study also, profitability performance rankings are compared with index price performances of manufacturing sub-sectors. Spearman's rank correlation coefficients show that there is generally no significant relationship between the index price rankings and profitability performance rankings of the manufacturing sub-sectors for the years 2019, 2020 and 2021. Only for the year 2021, positive and strong relationship is found between the rankings made with the Entropy-TOPSIS integrated method and the index price rankings.

The results of the study provide information to policymakers and manufacturing sector representatives in terms of profitability performances of manufacturing sector sub-sectors and their comparisons with each other. With the results of this study, it can be seen that the sub-sectors that stand out or lag behind in terms of profitability performance in the 2019-2021

period on the basis of sub-sectors. In addition, the effect of the pandemic on the performances of sub-sectors gives an idea about which sub-sectors are more or less affected by the pandemic compared to the pre-pandemic period.

The study is also important in terms of revealing the sub-sectors that showed a decline in profitability performance compared to 2019. The results show that the performance ranking of the Food, Beverage and Tobacco sub-sector is getting worse in 2020 and 2021 compared to 2019, according to the results of all combined MCMD methods used. For this reason, it is recommended to analyze the reasons for the negative change in the ranking experienced in this sub-sector compared to the others. In addition, the analysis of whether this improvement in the sub-sectors of Paper and Paper Products, Printing and Publishing and Textile, Wearing Apparel and Leather, which improved the performance rankings of 2019 and 2020 compared to other sub-sectors in 2021, the second year of the pandemic, is due to the dynamics of the sectors or the reasons specific to the enterprises will be important for policymakers and investors. In addition, the results of this study will support the decision processes of investors by contributing to the estimation of the profitability performances of the manufacturing sub-sectors for the periods after 2021.

This study reveals that the CRITIC based VIKOR method can be used as an alternative method in the performance analysis of sectors, sub-sectors and enterprises. It is also one of the few studies comparing profitability performances of the manufacturing sub-sectors in the literature. Based on these issues, it is thought that in the academic studies to be carried out in the upcoming periods, financial performance can be analyzed with the CRITIC based VIKOR method or comparing the results of different combined methods and analysis can be made for both the manufacturing sector and sub-sectors of different sectors.

Also, the results support that instead of profitability results once changes in profitability in respective years can also be studied. For further studies, this approach can bring comparable results with what we reached out with this study. Although our study examines profitability performances of the sub-sectors comparatively during the pandemic, any study which uses differences in profitability results by years can comment on the effects of the pandemic on the sub-sectors' profitability.

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APPENDIX

Appendix: 1 Original Data

Original Data (Averages-2021)

Sub-Sector	Return on Asset	Return on Equity	Net Profit Margin	Gross Profit Margin	Operating Profit Margin	Cost of Sales/ Total Revenue
Basic Metal	13.30	31.82	10.09	20.29	17.21	79.71
Paper and Paper Products, Printing and Publishing	13.39	32.16	14.44	21.78	9.98	78.22
Chemicals, Petroleum Rubber and Plastic Products	14.99	32.07	15.75	27.94	17.27	72.06
Fabricated Metal Products, Machinery, Electrical Equipment and Transportation Vehicles	12.56	28.70	9.81	23.79	15.96	76.26
Non-Metallic Mineral Products	7.47	18.96	13.28	21.11	9.01	78.89
Textile, Wearing Apparel and Leather	9.46	20.08	14.15	31.81	19.94	69.39
Food, Beverage and Tobacco	7.87	14.69	10.08	20.64	11.65	79.39

Original Data (Averages-2020)

Sub-Sector	Return on Asset	Return on Equity	Net Profit Margin	Gross Profit Margin	Operating Profit Margin	Cost of Sales/ Total Revenue
Basic Metal	5.22	14.52	6.52	16.25	10.72	83.75
Paper and Paper Products, Printing and Publishing	4.26	8.91	-0.61	18.84	3.64	81.16
Chemicals, Petroleum Rubber and Plastic Products	12.46	26.09	13.27	28.14	17.76	71.86
Fabricated Metal Products, Machinery, Electrical Equipment and Transportation Vehicles	10.78	25.14	9.98	23.82	13.16	76.18
Non-Metallic Mineral Products	0.78	4.79	-4.94	16.39	3.15	83.61
Textile, Wearing Apparel and Leather	2.91	6.77	3.51	27.12	12.37	73.62
Food, Beverage and Tobacco	6.68	13.59	7.53	21.02	10.85	78.99

Original Data (Averages-2019)

Sub-Sector	Return on Asset	Return on Equity	Net Profit Margin	Gross Profit Margin	Operating Profit Margin	Cost of Sales/ Total Revenue
Basic Metal	1.54	4.24	2.30	13.60	7.52	86.40
Paper and Paper Products, Printing and Publishing	-0.04	1.29	-0.26	18.08	5.17	81.92
Chemicals, Petroleum Rubber and Plastic Products	8.65	17.84	10.44	24.36	13.07	75.64

Fabricated Metal Products, Machinery, Electrical Equipment and Transportation Vehicles	4.59	14.58	3.86	19.82	7.85	80.18
Non-Metallic Mineral Products	0.41	-1.41	0.58	15.39	-0.74	84.61
Textile, Wearing Apparel and Leather	3.84	8.74	4.89	23.26	9.91	77.28
Food, Beverage and Tobacco	6.07	14.36	5.81	20.83	7.38	79.17

Index Data

Sub-Sector	**31.12.2018**	**31.12.2019**	**31.12.2020**	**31.12.2021**
Basic Metal	1,840.03	2,426.15	4,244.71	7,549.84
Paper and Paper Products, Printing and Publishing	436.39	800.79	2,150.63	1,630.93
Chemicals, Petroleum Rubber and Plastic Products	1,049.64	1,198.35	1,862.44	2,898.57
Fabricated Metal Products, Machinery, Electrical Equipment and Transportation Vehicles	1,144.27	1,814.70	3,212.58	4,928.05
Non-Metallic Mineral Products	626.26	862.38	1,867.54	1,978.98
Textile, Wearing Apparel and Leather	279.60	461.18	863.61	1,029.67
Food, Beverage and Tobacco	1,027.50	1,399.07	2,025.54	2,183.89

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