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A Multi-Criteria Decision-Making Model for Performance Evaluation Based on PSI–PF-COBRA

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Abstract: The aim of this study is to evaluate the financial and economic performance of companies operating in the chemical, pharmaceutical, petroleum, and plastic products sectors traded on Borsa Istanbul (BIST) within a holistic framework. Because traditional financial ratio analyses alone are insufficient, the study integrates the PSI and PF-COBRA methods, which are multi-criteria decision-making methods. The study first examines the sector's place in the Turkish economy, its relationship with macroeconomic indicators, and the interactions between growth, investment, and foreign trade in detail. Then, using data from the 2023/12 period, 15 companies traded on the BIST were evaluated based on 14 criteria. Criteria weights were determined based on the opinions of decision-makers from various expert groups. During the analysis, the importance of the criteria was first determined using the PSI method, and then the PF-COBRA method was used to rank the companies in terms of their distance from ideal and anti-ideal solutions. The results reveal that companies in the sector perform at different levels in terms of financial strength and economic competitiveness. According to the findings, companies with high R&D investments, strong export capacity, and balanced leverage rank higher, while companies with high leverage and limited R&D and innovation capacity remain at the bottom. The research's contributions are highlighted in three dimensions: (i) the joint analysis of financial and economic indicators in the Turkish chemical sector, (ii) the adaptation of the PSI–PF–COBRA method integration, which has limited application in the literature, to the sector, and (iii) the provision of a strategic decision-support tool for investors, managers, and policymakers. The study's results shed light on the development of policies and investment strategies that will enhance the sector's sustainable growth capacity and competitiveness.

Keywords: Industrial engineering, Multi-criteria decision making, PSI, PF-COBRA

Introduction

The performance of industrial sectors in the Turkish economy is critical for sustainable growth and competitiveness. Among these sectors, the chemicals, pharmaceuticals, petroleum, rubber, and plastic products sectors occupy a strategic position due to their large production capacity, central role in the intermediate goods supply chain, and contribution to exports. The chemical industry, which provides raw materials to many sectors such as textiles, automotive, agriculture, energy, and construction, has become more complex and dynamic due to globalization and fluctuations in energy prices. In this context, indicators such as companies' financial strength, liquidity level, debt structure, profitability, and operating efficiency are critical for both company sustainability and the sector's macroeconomic contribution. However, assessments based solely on financial ratios may be insufficient to fully explain companies' competitiveness today. Economic performance indicators such as export capacity, R&D investments, innovation level, and market share have become important complementary factors in

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determining a company's long-term position. Therefore, evaluating financial and economic indicators together produces more reliable results in demonstrating a company's holistic performance. In this context, multi-criteria decision-making (MCDM) methods enable comparative analysis of companies by considering multiple criteria simultaneously. Fuzzy logic-based methods are gaining prominence in such studies, where expert assessments involving uncertainty are increasingly important. The PF-COBRA (Picture Fuzzy Comprehensive Distance-Based Ranking) method used in this study reflects uncertainty more realistically by modeling the degrees of acceptance, rejection, and uncertainty in decision-makers' evaluations.

The use of multi-criteria decision-making (MCDM) methods in financial performance analyses has increased significantly in recent years; these methods have become an important tool for measuring the multidimensional performance of firms by enabling the combined evaluation of financial ratios and non-financial strategic indicators. Ertuğrul & Karakasoglu (2009) evaluated Turkish cement companies using the FAHP and TOPSIS methods, demonstrating that integrating subjective expert judgments with financial ratios increases ranking accuracy. Similarly, Secme et al. (2009) analyzed five large commercial banks using the FAHP–TOPSIS model and demonstrated that combining financial and non-financial criteria using the Balanced Scorecard provides more holistic results.

Studies following this approach have used various combinations of the BSC framework and fuzzy logic. Wu et al. (2009) evaluated banking performance using the fuzzy MCDM method, while Mandić et al. (2014) evaluated Serbian banks using the FAHP–TOPSIS, demonstrating that CAMELS indicators can be successfully integrated into MCDM models. The increased predictive power of hybrid models was emphasized by Wanke et al. (2016) in a study using artificial neural networks and TOPSIS together. Aras et al. (2017) determined that the economic dimension was the dominant criterion by measuring sustainability performance with the Entropy–TOPSIS approach. In the case of Borsa Istanbul, Bulgurcu (2012) reduced numerous financial ratios to a single index using the TOPSIS method; Liew et al. (2022) demonstrated that criteria interactions significantly impacted ranking results using the Entropy–DEMATEL–TOPSIS approach. Lam et al. (2021) analyzed companies in the construction sector with fuzzy VIKOR, noting that the method's accommodative structure well reflects different risk profiles. In Europe and the Middle East, studies using intuitive fuzzy approaches (Reig-Mullor & Brotons-Martinez, 2021), the modified EDAS model (No et al., 2021), and studies using SWARA-II, MEREC, and MARCOS together in the post-pandemic period (Ünlü et al., 2022) are noteworthy. Recent comparative studies have highlighted the sensitivity of the Entropy–TOPSIS and Entropy–VIKOR methods (Türegün, 2022), the impact of IT2-Fuzzy DEMATEL–TOPSIS on FinTech investments (Kou et al., 2021), and the superiority of multi-method consensus (Kaya et al., 2024). Furthermore, the MARCOS method has been reported to be successful in financial resilience analyses (Mastilo et al., 2024).

PSI (Preference Selection Index) and PF-COBRA (Picture Fuzzy COBRA) methods have become prominent approaches in the MCDM literature because they reduce the need for criterion weighting and offer a more flexible evaluation under uncertainty. The PSI method was first introduced by Maniya & Bhatt (2010) and applied to the material selection problem, demonstrating the feasibility of an unweighted prioritization process. Ongoing studies have shown that PSI produces consistent results across different sectors. For example, Attri & Grover (2015) successfully applied the method in production system design, and Madić et al. (2017) successfully applied it to the optimization of laser cutting parameters. In the banking sector, Kabakçı & Sarı (2019) and Trung et al. (2024) demonstrated that PSI produces rankings consistent with CAMELS indicators. Recently, models combining PSI with methods such as TOPSIS, MABAC, and SRP in a hybrid manner (Wardany & Zahedi, 2025) have provided more stable results. Studies on the COBRA and PF-COBRA methods are particularly concentrated in the fields of logistics, sustainability, tourism, and finance. Krstić et al. (2022) applied COBRA to reverse logistics; Popović et al. (2022) applied the MEREC–COBRA model to e-commerce strategy selection, demonstrating that objective weighting strengthens ranking stability. Tadić et al. (2024) analyzed the obstacles to drone use in last-mile logistics using fuzzy COBRA, indicating that the method effectively models uncertainty. Furthermore, applications of SWARA–COBRA in a global fuzzy environment (Zorlu et al., 2024) and SWARA–MEREC–COBRA in sustainability performance (Taşcı, 2024) demonstrate the method's adaptability to a wide range of decision-making domains. Studies demonstrating the effectiveness of MEREC–COBRA for the airline industry (Asker, 2024) are also available in the literature. The fact that the PF-COBRA method using picture fuzzy space reflects uncertainty more accurately was confirmed by Alshamrani et al. (2025) in the analysis of distance education software.

In this study, the financial and economic performance of 15 chemical and plastics sector companies traded on Borsa Istanbul was analyzed using the e method. The criteria set consists of indicators such as liquidity, debt, productivity, profitability ratios, R&D expenditures, number of R&D employees, market concentration, and export/sales ratio. Criteria weights are based on the assessments of three decision-makers: a financial analyst, a sector manager, and an R&D expert. The study is important in terms of (i) contributing to the holistic evaluation of financial and economic performance in the sector, (ii) adapting the PF-COBRA method, which has limited application in the literature, to a new sector, and (iii) the results obtained are guiding investors and policy makers.

Method

PSI (Preference Selection Index) Method

The PSI (Preference Selection Index) method is a nonparametric method that evaluates the performance of alternatives in multi-criteria decision-making (MCDM) problems without the need for criterion weights. Developed by Maniya and Bhatt (2010), PSI has rapidly become widespread in the literature due to its ease of calculation and applicability, especially in problems involving a large number of criteria. Because the method is based on simple steps such as normalization, averaging, deviation analysis, and obtaining a preference index, it has a wide range of applications in engineering, manufacturing, finance, and service sectors.
How the PSI Method Works (Summary Steps):

1. Creating the Decision Matrix: The decision matrix, consisting of the m-criterion and the n-alternative, is obtained as

$$X = [x_{ij}]_{m\times n}$$

2. Normalization: The decision matrix is normalized so that all criteria can be compared at a common scale.
   Benefit-type criteria:

$$n_{ij} = \frac{x_{ij}}{\max_j x_{ij}} \quad ;$$

   Cost-type criteria:

$$n_{ij} = \frac{\min_j x_{ij}}{x_{ij}} \quad ;$$

   Thus, the normalized decision matrix,

$$N = [n_{ij}]_{m\times n}$$

   is obtained.
3. Calculating Criteria Mean Values (Mi Score)
4. The average of the normalized values for each criterion is calculated.
5. Calculating Mean Deviations. The deviations of the alternatives from the criteria means are determined.
6. Obtaining PSI Scores and Ranking. Preference indices derived from the deviations are calculated, and alternatives are ranked according to the highest PSI value.

The PF-COBRA Method

The PF-COBRA method is an extension of the classical COBRA (Comprehensive Distance-Based Ranking) method using Picture Fuzzy Set (PFS) theory. It offers a powerful alternative for situations where decision-makers' evaluations involve uncertainty and contradictions in multi-criteria decision-making (MCDM) problems. The method ranks alternatives by measuring their distances from ideal and anti-ideal solutions, but in doing so, it evaluates criteria-related data in the form of picture fuzzy numbers (PFS - Picture Fuzzy Sets). As a combination of these two approaches, PF-COBRA is a powerful and versatile method for managing this uncertainty.

In recent years, methods integrated with Picture Fuzzy Sets (PFS) have gained importance to more accurately model uncertainty in decision-making processes. In this context, the PF-COBRA method is a version of the classical COBRA approach, enhanced with Picture Fuzzy Sets (PFS). PF-COBRA allows ranking alternatives according to ideal and anti-ideal solutions using comprehensive distance measures.

Picture Fuzzy Set (PFS) is a generalized form of classical fuzzy set and intuitionistic fuzzy set structures. PFS was introduced by Cuong & Kreinovich (2014). While classical fuzzy sets only answer the question "how many members does an element have?", PFS addresses the following three questions:

- "How many positive members does an element have?" → $\mu^{+}(x)$
- "Is an element undecided or neutral?" → $\mu^{0}(x)$

- "How many negative members does an element have?" → $\mu^{-}(x)$

This structure is particularly suitable for modeling situations such as uncertainty, hesitation, and indecision, which are frequently encountered in human-based decision-making situations. A Pictorial Fuzzy Set (PFS) over the universal set X is defined as follows:

$\tilde{A} = \{\langle x, \mu^{+}(x), \mu^{0}(x), \mu^{-}(x)\rangle \mid x \in X\}$
Where;
$\mu^{+}(x) \in [0,1]$: Positive membership degree
$\mu^{0}(x) \in [0,1]$: Neutral (abstaining) degree
$\mu^{-}(x) \in [0,1]$: Negative membership degree

The sum of the three membership functions cannot exceed 1. This indicates that each evaluation contains uncertainty and the total information level is kept under control.

The PF-COBRA method is implemented with the following basic steps:

1. Creating the PFS Decision Matrix: Decision makers' evaluations for each alternative and criterion are expressed as pictorial fuzzy numbers.
2. PFS Normalized Matrix: It is created by normalizing the membership, opposition, and abstention values. The normalization process is performed using the following formulas for the Benefit Criteria (Maximum). The aim is to increase positive membership, decrease negative membership, and preferably maintain neutrality constant.

   Positive membership $\mu^{+}_{ij(norm)} = \frac{\mu^{+}_{ij} - \min(\mu^{+}_{j})}{\max(\mu^{+}_{j}) - \min(\mu^{+}_{j})}$

   Negative membership $\mu^{-}_{ij(norm)} = \frac{\max(\mu^{-}_{j}) - \mu^{-}_{ij}}{\max(\mu^{-}_{j}) - \min(\mu^{-}_{j})}$

   Neutral (abstaining) Usually kept constant $\mu^{0}_{ij(norm)} = \mu^{0}_{ij}$

   For Cost Criteria;

   Positive membership $\mu^{+}_{ij(norm)} = \frac{\max(\mu^{+}_{j}) - \mu^{+}_{ij}}{\max(\mu^{+}_{j}) - \min(\mu^{+}_{j})}$

   Negative membership $\mu^{-}_{ij(norm)} = \frac{\mu^{-}_{ij} - \min(\mu^{-}_{j})}{\max(\mu^{-}_{j}) - \min(\mu^{-}_{j})}$

   Neutral (abstaining) Usually kept constant $\mu^{0}_{ij(norm)} = \mu^{0}_{ij}$
3. Determining Ideal and Anti-Ideal PFS Scores: The best and worst values for all criteria are defined in a pictorial fuzzy format. The ideal (best) and anti-ideal (worst) values are determined for each criterion. These values are derived from the normalized PFS matrix:

   Ideal PFS (PFS+): $\tilde{A}^{+} = (\max_{i} \mu^{+}_{ij}, \min_{i} \mu^{0}_{ij}, \min_{i} \mu^{-}_{ij})$

   Anti-Ideal PFS (PFS-): $\tilde{A}^{-} = (\min_{i} \mu^{+}_{ij}, \max_{i} \mu^{0}_{ij}, \max_{i} \mu^{-}_{ij})$
4. Distance Measurement: The comprehensive distances of the alternatives to the ideal and anti-ideal points are calculated. This is usually done with distance measures such as Euclidean, Hamming, or Manhattan. The distance between two Picture Fuzzy Number [$\tilde{A}_i = (\mu^{+}_{i}, \mu^{0}_{i}, \mu^{-}_{i})$ and $\tilde{A}_j = (\mu^{+}_{j}, \mu^{0}_{j}, \mu^{-}_{j})$] is usually It is measured by the following methods:

   Euclidean Distance: $D^{Euc}_{ij} = \sqrt{1/3[(\mu^{+}_{i} - \mu^{+}_{j})^2 + (\mu^{0}_{i} - \mu^{0}_{j})^2 + (\mu^{-}_{i} - \mu^{-}_{j})^2]}$

   Manhattan Distance: $D^{Man}_{ij} = 1/3[|\mu^{+}_{i} - \mu^{+}_{j}| + |\mu^{0}_{i} - \mu^{0}_{j}| + |\mu^{-}_{i} - \mu^{-}_{j}|]$

   Hamming Distance: $D^{Ham}_{ij} = |\mu^{+}_{i} - \mu^{+}_{j}| + |\mu^{0}_{i} - \mu^{0}_{j}| + |\mu^{-}_{i} - \mu^{-}_{j}|$

5. Calculating the Comprehensive Score: A score function is calculated that takes into account the proximity to the ideal solution and the distance to the anti-ideal solution.

$$S_i^{(Euc)} = \frac{D_i^{-(Euc)}}{D_i^{-(Euc)} + D_i^{+(Euc)}}$$

$$S_i^{(Man)} = \frac{D_i^{-(Man)}}{D_i^{-(Man)} + D_i^{+(Man)}}$$

$$S_i^{(Ham)} = \frac{D_i^{-(Ham)}}{D_i^{-(Ham)} + D_i^{+(Ham)}}$$

$$S_i^{(Combined)} = 1/3(S_i^{(Euc)} + S_i^{(Man)} + S_i^{(Ham)})$$

6. Ranking: Alternatives are ranked from most suitable to least suitable based on the calculated score values.

The PSI-PF-COBRA Method

The PSI-PF-COBRA method is an integrated decision-making model that combines the statistically robust structure of the PSI (Preference Selection Index) method with the flexible structure of PF-COBRA, which can model uncertainties. This combination provides a powerful tool that supports both objective data-based decisions and takes into account subjective evaluations through a fuzzy structure.

While the PSI method generates scores based on data normalization and the evaluation of deviations, PF-COBRA handles these scores in a fuzzy structure and converts decision makers' evaluations into (μ, ν, π) format. These structures are integrated as follows:

1. Calculating PSI Weights: The weights of the decision criteria are determined using the PSI method.
2. Creating PFS Values: The evaluation of each alternative against each criterion is expressed in the PFS structure.
3. Creating the Normalized PFS Matrix: The data is normalized in (μ, ν, π) format.
4. Determining Ideal and Anti-Ideal PFS Points: Ideal (best) and anti-ideal (worst) values are determined for all criteria.
5. Calculating Comprehensive Distances: The distance of each alternative to the ideal and anti-ideal solution points is calculated using PSI weights.
6. Determining the Score Function: The score value is calculated for each alternative by considering the proximity to the ideal point and the distance to the anti-ideal point.
7. Ranking the Alternatives: Alternatives are ranked according to the obtained score values.

This unified structure allows decision makers to consider statistical weights derived from historical data and make more accurate and reliable decisions in environments with blurred data and high uncertainty.

Results and Discussion

In this study, the 2023 financial performance of 15 companies listed on Borsa Istanbul (BIST) and operating in the chemicals, pharmaceuticals, petroleum, and plastics sectors was comprehensively analyzed. The companies included in the research were carefully selected from among the top 500 firms in Turkey in terms of R&D expenditures in 2023. This selection strategy enables the evaluation of firms that stand out not only with their financial performance but also with their innovation capacity, allowing for a holistic assessment of sector-leading companies. The dataset used in the analysis was compiled from publicly accessible and reliable institutional sources. Financial statements, ratio indicators, and R&D figures of the selected firms were obtained from the following platforms:

- ISO 500 Official Website (https://iso500.org.tr)
- Turkishtime Magazine – 2023 R&D 250 Report (https://turkishtimedergi.com)
- Fintables Financial Data Platform (https://fintables.com)
- Borsa Istanbul (BIST) and Public Disclosure Platform (KAP) (https://www.kap.org.tr/tr/bist-sirketler)

Based on ISO 500 and Turkishtime data, the companies with the highest sector-specific R&D expenditures were identified, and from among those listed on BIST, 15 companies were selected for detailed financial analysis. This approach ensured that the sample consists of firms that are simultaneously strong in R&D investment and actively valued in capital markets. Consequently, the study provides a comparative assessment of companies that lead their sectors both in terms of innovation capability and financial strength.

The following financial and economic indicators were used to evaluate the financial performance of companies in the chemicals, pharmaceuticals, petroleum, and plastics sectors listed on Borsa Istanbul:

- K1 – Current Ratio: Shows a company's ability to cover short-term liabilities. Values between 1.5–2 are considered healthy, especially in inventory-intensive sectors like chemicals and plastics.
- K2 – Cash Ratio: Measures cash and cash equivalents relative to short-term debt. It is the most conservative liquidity indicator. In high-investment sectors (plastics, petrochemicals), values may fall below the average due to investment cycles.
- K3 – Financial Debt Ratio: Indicates the share of assets financed by debt. High values signal debt-driven growth and financial risk, common in chemical and energy-intensive industries.
- K4 – Leverage Ratio: Shows total debt relative to equity, reflecting dependence on external financing. High leverage is typical in oil and petrochemical industries due to large-scale investments.
- K5 – Asset Turnover Ratio: Measures how efficiently assets generate sales. Very high values can indicate underinvestment, so industry context is essential.
- K6 – Receivables Turnover Ratio: Shows how frequently receivables are collected. High values indicate efficient cash management; low values may suggest collection issues.
- K7 – Gross Margin (%): Reflects the difference between production costs and sales revenue, indicating cost control and production efficiency.
- K8 – EBITDA Margin (%): Shows operational profitability independent of external factors. Typically ranges between 15–25% in chemical and plastics sectors.
- K9 – Net Profit Margin (%): Indicates net income generated from sales and reflects strategic performance.
- K10 – Return on Equity (%): Shows net profit relative to equity and is a key indicator of capital efficiency.
- K11 – R&D Expenditure (M TL): Represents financial resources allocated to innovation and technological development.
- K12 – Number of R&D Employees: Indicates a company's knowledge-creation capacity and technological investment.
- K13 – Market Share: Shows the company's relative position in the market.
- K14 – Export/Sales Ratio: Reflects the company's degree of export orientation.

As part of the research process, a three-person decision-making group comprised of field experts was formed to evaluate the criteria. Members of this group represented diverse areas of expertise, providing a comprehensive perspective throughout the evaluation process. Each expert contributed their unique knowledge and professional perspective, enhancing the robustness, validity, and reliability of the decision-making framework. The decision-makers were as follows:

- D1 – Financial Analyst: Possessing academic expertise in financial management and multi-criteria decision-making techniques, they contributed to the assessment of the financial strength dimension.
- D2 – Industry Representative: Possessing many years of managerial experience in the chemical and plastics sectors and incorporating practical sectoral knowledge into the assessment process.
- D3 – R&D Specialist: Manages the R&D and innovation processes of a large-scale industrial enterprise and ensured that an innovation and technology-focused perspective was incorporated into the decision-making process.

This diversification enabled a balanced consideration of financial strength, practical sectoral knowledge, and innovation dimensions in the assessments. The contribution of each decision-maker in their respective sub-areas was quantified using assessments on a scale of 1–10 (Table 1). As a result of these evaluations, D1 received the relatively highest scores in financial analysis, D2 in sectoral experience and D3 in R&D & innovation.

Table 1. Decision-maker performance scores (scale 1–10)

Decision-maker	Financial Analysis	Industry Experience	R&D & Innovation
D1 (Financial Analyst)	9	6	5
D2 (Industry Representative)	6	9	7
D3 (R&D Specialist)	5	7	9

As a result of the PSI calculations, the decision-maker weights were obtained as follows:

- D1 = 0.322 (32.2%)
- D2 = 0.345 (34.5%)
- D3 = 0.333 (33.3%)

As seen in Table 2, the criteria weights were determined using the PSI method in line with the opinions of the decision makers.

Table 2. The criteria weights

No	Criterion	Description	Type	D1	D2	D3	Weight (%)
1	Current Ratio	Indicates the company's ability to meet short-term liabilities.	Benefit	9	7	6	7.15
2	Cash Ratio	Measures the proportion of cash and cash equivalents to short-term obligations.	Benefit	9	6	5	6.49
3	Leverage Ratio	Represents the size of total liabilities relative to equity.	Cost	8	7	6	6.83
4	Financial Debt Ratio	Share of short- and long-term financial debt in total assets.	Cost	9	6	6	6.81
5	Asset Turnover Ratio	Measures how efficiently a company uses its assets to generate sales.	Benefit	7	8	7	7.18
6	Receivables Turnover Ratio	Indicates how quickly a company collects its receivables.	Benefit	7	8	7	7.18
7	Gross Profit Margin (%)	Shows the gross profitability generated from sales.	Benefit	8	7	7	7.16
8	EBITDA Margin (%)	Ratio of earnings before interest, taxes, depreciation, and amortization to net sales.	Benefit	8	7	7	7.16
9	Net Profit Margin (%)	Indicates the net profitability derived from sales.	Benefit	8	7	7	7.16
10	Return on Equity (ROE)	Shows how efficiently the company utilizes its equity.	Benefit	9	7	7	7.47
11	R&D Expenditure	Resources allocated to research and development activities.	Benefit	6	7	9	7.18
12	Number of R&D Employees	Number of personnel employed in the R&D department.	Benefit	6	7	9	7.18
13	Market Share	Represents the company's relative share in the market.	Benefit	6	9	7	7.20
14	Export-to-Sales Ratio	Indicates the proportion of total sales generated from exports.	Benefit	7	9	8	7.84

A data matrix was constructed by compiling information according to the criteria defined in the research framework. This matrix provides a systematic structure for evaluating the alternatives (companies) in line with the established criteria. By organizing the data in a coherent and comparable format, the matrix facilitates the effective application of multi-criteria decision-making methods and enhances the transparency and traceability of the evaluation process.

Table 3. Data matrix

Firm	K1	K2	K3	K4	K5	K6	K7	K8	K9	K10	K11	K12	K13	K14
Aksa Akrilik	1,42	0,5	33,07	14,39	0,95	8,91	16,52	16,92	6,9	10,09	150	120	2,6	52,5
Kalekim	1,85	0,72	34,57	6,71	1,29	5,46	38,65	21,77	9,22	18,78	80	75	0,47	5
Aygaz	1,12	0,39	20,93	4,81	1,41	16,02	7,65	1,8	9,18	17,83	60	50	5,99	14,2
Brisa	1,27	0,84	63,72	42,13	0,76	6,82	24,53	16,12	15,04	32,02	220	200	2,82	43,1
Dyo	1	0,11	65,15	32,61	0,87	4,06	23,44	10,42	3,83	9,11	90	85	0,88	5
Ege Profil	1,29	0,2	50,7	3,99	1,04	3,08	37,92	25,92	5,41	11,84	65	60	0,89	5
Hektaş	1,82	0,03	44,76	21,33	1,23	3,16	24,69	12,59	-8,44	-18,25	105	95	0,52	5,2
Kordsa	1,24	0,15	54,08	36,07	0,8	5,44	14,96	8,3	0,78	1,76	110	100	1,12	92,5
Marshall	1,04	0,46	64,12	17,01	1,26	9,21	31,56	11,7	-4,68	-25,98	95	88	0,4	5
Polisan	1,11	0,22	19,21	7,14	0,4	5,04	21,42	17,79	13,34	6,94	130	110	0,58	5
Sasa	0,82	0,15	56,62	43,04	0,37	5,54	18,8	17,08	39,28	34,21	140	125	4,71	27,5
Şişecam	1,69	0,67	42,61	29,28	0,52	5,05	27,59	13,64	11,26	12,01	190	170	7,85	43,1
Tüpraş	1,3	0,63	44,67	9,63	1,92	18,13	15,98	14,02	7,8	28,3	175	160	69,92	33,7
İşbir Sentetik	1,8	0,45	28,81	23,98	0,62	4,18	26	22,05	8,63	8,34	85	80	0,27	57,4
Kimteks	1,34	0,5	69,42	40,52	1,28	3,06	16,88	13,02	5,71	23,27	125	115	0,98	5

The fuzzy set decision matrices for the three decision makers were constructed based on their individual evaluations. Table 4 presents a sample section of the financial analyst's decision matrix. As illustrated, each criterion value is represented in a triple format, reflecting the membership, neutrality, and non-membership degrees within the picture fuzzy framework.

Table 4. A sample section of the financial analyst's decision matrix

Firm	Current ratio	Cash ratio	Asset turnover	Receivables turnover
Aksa Akrilik	(0.583; 0.367; 0.050)	(0.580; 0.370; 0.050)	(0.374; 0.576; 0.050)	(0.388; 0.562; 0.050)
Kalekim	(1.000; 0.000; 0.050)	(0.852; 0.098; 0.050)	(0.594; 0.356; 0.050)	(0.159; 0.791; 0.050)
Aygaz	(0.291; 0.659; 0.050)	(0.444; 0.506; 0.050)	(0.671; 0.279; 0.050)	(0.860; 0.090; 0.050)
Brisa	(0.437; 0.513; 0.050)	(1.000; 0.000; 0.050)	(0.252; 0.698; 0.050)	(0.250; 0.700; 0.050)
Dyo	(0.175; 0.775; 0.050)	(0.099; 0.851; 0.050)	(0.323; 0.627; 0.050)	(0.066; 0.884; 0.050)
Ege Profil	(0.456; 0.494; 0.050)	(0.210; 0.740; 0.050)	(0.432; 0.518; 0.050)	(0.001; 0.949; 0.050)
Hektaş	(0.971; 0.000; 0.050)	(0.000; 0.950; 0.050)	(0.555; 0.395; 0.050)	(0.007; 0.943; 0.050)
Kordsa	(0.408; 0.542; 0.050)	(0.148; 0.802; 0.050)	(0.277; 0.673; 0.050)	(0.158; 0.792; 0.050)
Marshall	(0.214; 0.736; 0.050)	(0.531; 0.419; 0.050)	(0.574; 0.376; 0.050)	(0.408; 0.542; 0.050)
Polisan	(0.282; 0.668; 0.050)	(0.235; 0.715; 0.050)	(0.019; 0.931; 0.050)	(0.131; 0.819; 0.050)
Sasa	(0.000; 0.950; 0.050)	(0.148; 0.802; 0.050)	(0.000; 0.950; 0.050)	(0.165; 0.785; 0.050)
Şişecam	(0.845; 0.105; 0.050)	(0.790; 0.160; 0.050)	(0.097; 0.853; 0.050)	(0.132; 0.818; 0.050)
Tüpraş	(0.466; 0.484; 0.050)	(0.741; 0.209; 0.050)	(1.000; 0.000; 0.050)	(1.000; 0.000; 0.050)
İşbir Sentetik	(0.951; 0.000; 0.050)	(0.519; 0.431; 0.050)	(0.161; 0.789; 0.050)	(0.074; 0.876; 0.050)
Kimteks	(0.505; 0.445; 0.050)	(0.580; 0.370; 0.050)	(0.587; 0.363; 0.050)	(0.000; 0.950; 0.050)

The PFS decision matrices of the decision makers were combined, taking into account the weights of the decision makers, and then the normalized PFS matrix was created. A portion of this matrix is shown in Table 5.

Table 5. Portion of the normalized PFS matrix

Firm	Current ratio	Cash ratio	Asset turnover	Receivables turnover
Aksa Akrilik	(0.583; 0.334; 0.084)	(0.580; 0.336; 0.084)	(0.374; 0.542; 0.084)	(0.388; 0.528; 0.084)
Kalekim	(1.000; 0.000; 0.084)	(0.852; 0.064; 0.084)	(0.594; 0.323; 0.084)	(0.159; 0.757; 0.084)
Aygaz	(0.291; 0.625; 0.084)	(0.444; 0.472; 0.084)	(0.671; 0.245; 0.084)	(0.860; 0.056; 0.084)
Brisa	(0.437; 0.479; 0.084)	(1.000; 0.000; 0.084)	(0.252; 0.665; 0.084)	(0.250; 0.667; 0.084)
Dyo	(0.175; 0.742; 0.084)	(0.099; 0.818; 0.084)	(0.323; 0.594; 0.084)	(0.066; 0.850; 0.084)
Ege Profil	(0.456; 0.460; 0.084)	(0.210; 0.706; 0.084)	(0.432; 0.484; 0.084)	(0.001; 0.915; 0.084)
Hektaş	(0.971; 0.000; 0.084)	(0.000; 0.916; 0.084)	(0.555; 0.362; 0.084)	(0.007; 0.910; 0.084)
Kordsa	(0.408; 0.509; 0.084)	(0.148; 0.768; 0.084)	(0.277; 0.639; 0.084)	(0.158; 0.758; 0.084)
Marshall	(0.214; 0.703; 0.084)	(0.531; 0.385; 0.084)	(0.574; 0.342; 0.084)	(0.408; 0.508; 0.084)
Polisan	(0.282; 0.635; 0.084)	(0.235; 0.682; 0.084)	(0.019; 0.897; 0.084)	(0.131; 0.785; 0.084)
Sasa	(0.000; 0.916; 0.084)	(0.148; 0.768; 0.084)	(0.000; 0.916; 0.084)	(0.165; 0.752; 0.084)
Şişecam	(0.845; 0.072; 0.084)	(0.790; 0.126; 0.084)	(0.097; 0.820; 0.084)	(0.132; 0.784; 0.084)
Tüpraş	(0.466; 0.450; 0.084)	(0.741; 0.176; 0.084)	(1.000; 0.000; 0.084)	(1.000; 0.000; 0.084)
İşbir Sentetik	(0.951; 0.000; 0.084)	(0.519; 0.398; 0.084)	(0.161; 0.755; 0.084)	(0.074; 0.842; 0.084)
Kimteks	(0.505; 0.411; 0.084)	(0.580; 0.336; 0.084)	(0.587; 0.329; 0.084)	(0.000; 0.916; 0.084)

In the next stage, the Ideal (A^+) and Anti-Ideal (A^-) solution points were calculated based on the criteria. Performance distances were calculated based on the companies' decision criteria, and score values were obtained accordingly. These distances and score values are presented in Table 6. According to the table, different distance calculation methods (Euclidean, Manhattan, and Hamming) were used for each company to determine both the distance from the ideal solution (D+) and the distance from the anti-ideal solution (D-). Furthermore, based on these distances, the relevant performance scores (S) were calculated for each method. For example, for Tüpraş, the Euclidean distance was determined as 0.2474 for the ideal point, and 0.5361 for the anti-ideal point, resulting in a performance score of 0.6843.

Generally, performance scores reflect the relative advantages of the companies within the decision criteria. Low D+ and high D- values indicate that the company is close to the ideal solution and therefore has high performance. Conversely, high D+ and low D- values indicate that performance is far from ideal. The different distance and score calculations in the table enable a multidimensional assessment in the analysis and clearly reveal to decision-makers the relative performance differences between companies.

The performance scores obtained from the PF-COBRA calculations were ranked from highest to lowest. Tüpraş, which achieved the highest comprehensive performance score in both Euclidean and Manhattan distance measures, emerges as the clear leader of the analysis. Its dominance is supported by large-scale production capacity, high market share, strong operational profitability, and a relatively balanced financial structure. This performance positions Tüpraş as a benchmark firm in the sector.

Table 6. Distance and score values

Firm	D+ Euc	D– Euc	S_Euc	D+ Man	D– Man	S_Man	D+ Ham	D– Ham	S_Ham	S_Com
Tüpraş	0.2474	0.5361	0.6843	0.1999	0.4376	0.6864	0.5997	1.3127	0.6864	0.6857
Kalekim	0.3595	0.4239	0.5411	0.2915	0.3460	0.5427	0.8745	1.0380	0.5427	0.5422
Şişecam	0.3717	0.4117	0.5255	0.3013	0.3362	0.5273	0.9040	1.0085	0.5273	0.5267
Brisa	0.3745	0.4079	0.5214	0.3046	0.3329	0.5222	0.9138	0.9987	0.5222	0.5219
Aksa Akrilik	0.3862	0.3964	0.5065	0.3138	0.3237	0.5077	0.9414	0.9710	0.5077	0.5073
İşbir Sentetik	0.4166	0.3667	0.4681	0.3381	0.2994	0.4696	1.0143	0.8981	0.4696	0.4691
Polisan	0.4665	0.3161	0.4039	0.3794	0.2580	0.4048	1.1383	0.7741	0.4048	0.4045
Aygaz	0.4699	0.3131	0.3999	0.3819	0.2556	0.4010	1.1456	0.7669	0.4010	0.4006
Ege Profil	0.4718	0.3103	0.3967	0.3842	0.2532	0.3972	1.1527	0.7597	0.3972	0.3971
Sasa	0.4987	0.2832	0.3622	0.4063	0.2311	0.3626	1.2190	0.6934	0.3626	0.3625
Kimteks	0.5224	0.2599	0.3322	0.4253	0.2122	0.3329	1.2759	0.6366	0.3329	0.3326
Kordsa	0.5293	0.2526	0.3231	0.4313	0.2062	0.3234	1.2939	0.6186	0.3234	0.3233
Hektaş	0.5354	0.2469	0.3156	0.4359	0.2016	0.3162	1.3078	0.6047	0.3162	0.3160
Marshall	0.5396	0.2426	0.3102	0.4394	0.1981	0.3107	1.3182	0.5942	0.3107	0.3105
Dyo	0.5976	0.1843	0.2357	0.4870	0.1505	0.2360	1.4610	0.4514	0.2360	0.2359

Tüpraş's first-place ranking reflects its economies of scale and market leadership in Turkey's industrial and energy sectors. High capacity utilization and strong sales revenues further demonstrate its contribution to domestic and international trade. Its balanced debt structure indicates an ability to maintain sustainable profitability even in tight monetary conditions. Companies such as Kalekim, Şişecam, Brisa, and Aksa Acrylic, which follow Tüpraş, underline the importance of export performance and R&D investments for sectoral competitiveness. Their strong financial stability and integration with global markets significantly contribute to the sector's export capacity. In particular, Şişecam has strengthened its technological capabilities in glass and chemical products through rising R&D investments.

Companies in the middle group—İşbir Sentetik, Polisan, Aygaz, Ege Profil, and Sasa—exhibit a more mixed performance. Although they perform well in certain criteria, their overall scores are more moderate. For instance, despite Sasa's high profitability, its elevated debt level indicates potential financial fragility. Likewise, companies such as Aygaz and Polisan remain more vulnerable to macroeconomic fluctuations due to their reliance on the domestic market. Firms in the lower group-Kordsa, Marshall, Dyo, Hektaş, and Kimteks-fell behind largely due to high leverage, low return on equity, and limited export performance. Their relatively smaller scale restricts their ability to achieve competitive advantages, while lower levels of R&D investment reduce their capacity to adapt to technology-intensive production environments.

Overall, the findings show that economic success in the chemicals and related sub-sectors depends not only on balance-sheet indicators but also on export capacity, market share, and technological innovation. While large-scale companies such as Tüpraş and Şişecam maintain their leadership through economies of scale, medium-scale firms can enhance their competitiveness by expanding export activities and increasing R&D investments. For smaller companies, strengthening financial structures and improving innovation capabilities are critical for long-term sustainability.

Conclusion

This research provides a comprehensive evaluation of the financial and economic performance of 15 chemical and plastics sector companies listed on Borsa Istanbul using the PF-COBRA method. The results reveal that differences in company performance stem not only from financial ratios but also from strategic variables such as export intensity, market positioning, and R&D investment capacity. This multifaceted assessment helps explain the sector's economic contribution through production efficiency, economies of scale, and innovation capability. Tüpraş ranks first with a considerable margin, confirming its leadership role driven by scale advantages, high profitability, and strong export capacity. Kalekim, Şişecam, Brisa, and Aksa Acrylic follow as the top-performing group, characterized by low financial risk, strong operational margins, and consistent investments in export-oriented and innovation-driven strategies.

The middle-performing companies show potential but require improvements in financial resilience and strategic diversification. Sasa's case clearly illustrates the importance of prudent debt management despite high profitability. Aygaz and Polisan also highlight the risks associated with domestic market dependency. Companies in the lower tier face structural limitations in profitability, R&D capacity, and export performance, which restrict their competitiveness. Their results underline the importance of scaling up technological investments and strengthening financial structures.

The PF-COBRA combined score—integrating Euclidean, Manhattan, and Hamming distances—provides a reliable and holistic perspective on firms' strengths and weaknesses. The method's ability to incorporate decision-maker uncertainty enhances both the academic and practical relevance of the findings. From an economic standpoint, the results emphasize the need for medium- and small-scale firms to expand their export markets, increase innovation-driven investments, and manage debt structures more effectively. Sector-wide sustainability can be strengthened by policies that promote R&D capacity, export competitiveness, and financial stability.

In conclusion, sustainable competitiveness in the chemicals and plastics sector requires integrated management of financial stability, export capacity, and innovative activities. Firms that successfully balance these factors will be better positioned to contribute to both sectoral development and national economic growth.

Recommendations

Future research could conduct comparative analyses by applying the PF-COBRA method to different sectors. Furthermore, the robustness of the results could be tested by conducting comparative studies with other MCDM methods (TOPSIS, VIKOR, AHP). This would allow for the development of more comprehensive and reliable policy recommendations to enhance the sector's competitiveness.

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* The authors declare that the scientific ethical and legal responsibility of this article published in EPSTEM journal belongs to the authors.

Conflict of Interest

* The authors declare that they have no conflicts of interest

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