



An Integrated Ranking Model of Tehran Stock Exchange Companies Using Bayesian Best-Worst, CoCoSo, and MARCOS Methods (Case Study: Food and Beverage Companies)

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ABSTRACT

The primary goal of this research is to use Multi-Criteria Decision-Making (MCDM) methods to assess the performance and rank the firms listed on the Tehran Stock Exchange in the food and beverage industry. The calculation of financial ratios is a principal performance appraisal method. Some of these ratios were utilized to rank companies in this study. Nonetheless, the most challenging problem with studying financial ratios is that each financial metric examines a different facet of a company's financial performance. As a result, managers and investors may be confused by financial ratios. Hence, solutions are required to overcome these constraints. MCDM methods can provide solutions. As a new MCDM method, the Bayesian Best-Worst was utilized to weight options in this study, given its benefits such as enhanced effectiveness of weights resulting from integrating multiple expert opinions and calculating factor ranking reliability. In addition, in light of the characteristics of MCDM methods, the CoCoSo and MARCOS methods were used to rank 14 firms listed on the Tehran Stock Exchange in the food and beverage industry over three years (2018-2020). Ultimately, the Borda and Copeland methods were built on to integrate the results of the methods.

Keywords: Ranking, Performance Appraisal, Multi-Criteria Decision-Making, Bayesian Best-Worst Method, CoCoSo Method and MARCOS Method.

1. Introduction

One of the most important components of the financial market in the economy of any country is the stock market. The stock exchange is a center for the accumulation of savings and liquidity of the private sector with the purpose of financing long-term investment projects and is considered an official and reliable reference for the holders of stagnant savings. The stock market's primary function is to equip public savings for optimal allocation. The stock market not only encourages varied savers to invest in production but also converts short-term financial resources into long-term uses (Zeinoldini et al., 2020). Moreover, one of the fundamental functions of the stock market is to allocate scarce capital resources in an optimal way (Al-Imran and Al-Imran, 2013). The Iranian stock exchange comprises corporations from numerous industries, including the food and beverage sector. Regarding the significance of the food and beverage industry in people's lives, it is essential to analyze the performance of the companies within this sector as a measure to enhance this industry's performance and growth. Awareness of each firm's performance level relative to its peers in this industry has an important impact on the performance and advancement of the industry. Performance analysis of firms can be a significant step in building a competitive business environment and establishing the top company as a model for individual companies to improve and enhance their performance (Amiri et al., 2018).

One way to prioritize and rank companies is performance appraisal. Performance appraisal and management plays a crucial role for firms in today's competitive economic environment, which is characterized by a scarcity of resources (Amado et al., 2012). In the context of intense business competition, it is essential to well understand the performance appraisal system, including financial and operational ratios. In addition, a comparison of inter- and intra-organizational relationships needs to be performed so that the performance evaluation could produce meaningful and helpful results (Vaidya and Chitnis, 2012). Businesses must continuously monitor their performance across multiple dimensions in today's competitive marketplace. It is, therefore, understandable that the development of a performance appraisal system is a challenging issue for managers more than ever before (Carlucci, 2010). The organization employs performance appraisal as a

process and criterion for measuring the efficacy and efficiency of its past actions. A performance appraisal system is a collection of metrics used to quantify the efficiency and effectiveness of operations (Neely et al., 2005).

There are numerous approaches to evaluating the performance of businesses, including the performance pyramid model, the balanced scorecard model, the European Foundation for Quality Management (EFQM) excellence model, and the corporate financial performance evaluation. The performance pyramid model represents the first effort to develop an integrated system for measuring performance. The model of the performance pyramid consists of four levels: At the top of the pyramid is the company's mission statement, which is reinforced by lower levels, namely, business units, business operating systems, and work centers. The performance pyramid is intended to connect the organization's strategy and operations. This model incorporates both internal and external performance assessments. To tie strategies to operations, metrics ascend the pyramid, whereas objectives descend (Taticchi and Balachandran, 2008).

The balanced scorecard model is utilized in virtually all public and private organizations. This model describes, implements, and manages strategies at all organizational levels. The balanced scorecard model focuses on four criteria or metrics, i.e., the financial, customer, internal process, learning and growth metrics (Lop et al., 2018).

The EFQM excellence model is the most widely used organizational framework in Europe. The organizational excellence model aims to offer a unified perspective on performance management. The organizational excellence model is a practical instrument that an organization can utilize in a variety of ways: as a tool to evaluate the organization, as a procedure to benchmark itself against other organizations, as a guide to identifying areas for improvement, as a common vocabulary base and thinking method, and as a framework for an organizational management system (Dror, 2008).

The financial performance appraisal is one of the most prominent appraisal models, and it is a crucial procedure for industries in the present competitive environment. Designing an accurate and adequate performance appraisal framework benefits employees and company shareholders (Shaverdi et al., 2016). Consequently, financial information is utilized to

assess operational performance. Financial ratio analysis is typically utilized to analyze a firm's success (Ou, 2016).

Numerous scholars and practitioners have found assessing a company's performance using a set of financial measurements and ratios to be both intriguing and demanding. Every decision-maker needs to identify factors that may accurately predict a company's performance, especially financial ones (Delen et al., 2013). Financial ratios are used to identify the strengths and weaknesses of a business. They illustrate the significant links between a company's resources and cash flow. Ratio analysis gives a record in a sense. According to these ratios, the success rate of the firm's management may be determined (Liesz and Maranville, 2008).

In analyzing financial ratios, it is critical to remember that each financial metric evaluates a specific aspect of an organization's financial performance. Moreover, aggregating different groups of financial ratios is not an easy task, and it is impossible to comment on their totality. Managers and investors may be confused by financial ratios due to these limitations. Therefore, researchers are searching for methods to circumvent these limitations. One of the solutions for ranking and evaluating company performance is to use Multi-Criteria Decision-Making (MCDM) methods. These methods have proved more efficient in comparing and evaluating companies.

One of the new MCDM methods is the Bayesian best-worst method, which is used to allocate weights to criteria. A salient feature of this method, compared to other MCDM methods, is that the weights resulting from the MCDM problem are made more effective in integrating multiple expert opinions and calculating the confidence level of factor ranking (Mohammadi and Rezaei, 2020).

This study examined the financial performance of 14 companies in the food and beverage industry from 2018 to 2020 using MCDM including Bayesian best-worst method to weight the selected criteria. The study also utilized CoCoSo and MARCOS methods to rank the food and beverage companies listed on the Tehran Stock Exchange and compared the results of these methods. MCDM methods are categorized into compensatory and non-compensatory models, with multiple subgroups for each model. Compensatory models allow the exchange of criteria, and the decision-maker is willing to exchange criteria. In

addition, the change in one criterion is counterbalanced by a change in another criterion or criteria. Non-compensatory models are those that prohibit the exchange of criteria. In other words, the weakness of one criterion is not offsetted by the strength of another criterion, and the decision-maker is unwilling to swap criteria. Furthermore, each criterion serves independently as the basis for evaluating other options.

Given the permissible inter-criterion exchange, the models of the selected methods in this study are of the compensatory type. Compensatory models consist of three subcategories. The first subgroup involves coordinated models, whose output is a set of rankings that will provide the necessary coordination more efficiently. The second subgroup comprises compromise models, whose preferred option is the one that is closest to the ideal solution. This subgroup includes the CoCoSo and MARCOS methods. Lastly, scoring models constitute the third subgroup, which attempts to estimate a utility function for each option, from which the most desirable option is selected. The concern in this subgroup is how to estimate the multi-criteria utility function (Asgharpour, 2008). The BWM and Bayesian best-worst methods fall within this subgroup.

The methods utilized in this investigation fall under the compromise and scoring subgroups of compensatory models. CoCoSo and MARCOS methods were selected from the compromise subgroup because of their respective advantages. The MARCOS method has the advantages of simplicity, flexibility, stability, dependability, stability in acceptance of big data, ideal and counter-ideal values, relationships between options and ideal and anti-ideal values, and greater precision than other MCDM methods, particularly TOPSIS. The desirability of options relative to ideal and counter-ideal solutions is a potent tool for optimizing multiple objectives (Stevi et al., 2020). The CoCoSo method intends to establish specific modifications to the primary structure. The normalized criterion values, weighted comparability sequence, and exponential weight of comparability sequences for each option are determined to reach this objective. This method has the advantage of combining three strategies to create a comprehensive method for structured and sustaining decision-making (Yazdani et al., 2018).

Therefore, this research addresses these two questions:

- What are the financial criteria and their relative weights for evaluating performance of firms in the food and beverage industry?
- What is the ranking of the selected firms in the food and beverage industry according to MARCOS and CoCoSo methods?

2. Literature Review

Numerous studies have utilized MCDM methods to evaluate and rank stock exchange companies. In an article, Rouhani rad et al. (2022) evaluated the performance of 15 companies from the cement industry of the Tehran Stock Exchange using the six financial criteria of ROE, ROA, profit margin, asset turnover ratio, interest coverage ratio, and current ratio from 2016 to 2018. The researchers used the BWM method for weighting, and TOPSIS, ELECTRE, and VIKOR as well as the BWM method for ranking. The results of the research indicate that the equity rate ratio has more weight and importance than other criteria. Lam et al. (2021) evaluated the performance of 20 construction companies from 2015 to 2019 using the integrated model Entropy- Fuzzy VIKOR and the criteria of return of equity, return on assets, earnings per share, debt to equity ratio, debt to assets ratio, and current ratio. They highlighted the significant role of construction in economic development and the government's attention and encouragement of the construction industry during the COVID-19 pandemic. Because uncertainty plays a significant role in decision-making, they employed the Entropy and Fuzzy VIKOR methods for weighting and ranking, respectively.

Aldalou and Perçin (2020) evaluated the performance of 21 companies in the food and beverage industry of the Istanbul Stock Exchange using the five main criteria of profitability ratios, leverage ratios, growth ratios, liquidity ratios, efficiency ratios, and market ratios, as well as 18 sub-criteria through MCDM methods during 2015 to 2017. Given the urgent need for a reliable and consistent decision-making approach, they employed Fuzzy Shannon's Entropy (FSE) and CRITIC methods for weighting and used FEDAS, FCOPRAS, FMOORA, FVIKOR, FTOPSIS, FSAW, and average methods for ranking. They also applied the Spearman correlation coefficient to compare the methods. The results of their study indicated that profit margin and income growth were

the most important criteria for performance evaluation. The results also revealed that the FEDAS method correlated with FMOORA, FVIKOR, and FSAW methods and with the mean of the methods.

Vuković et al. (2020) applied a combined MCDM method and modern portfolio theory to the study of stock selection using criteria such as return, standard deviation, volume, beta, EPS, ROE, P/B, P/S, and ROA from 2017 to 2019. The researchers once used the AHP method for weighting and SAW, TOPSIS, Linear Assignment, PROMETHEE, and COPRAS methods, as well as a combination of these rating methods. Moreover, they used modern portfolio theory regarding risk and return for ranking. Additionally, the Spearman correlation was used to compare the methods. The results illustrated a significant difference between ranking by new methods of MCDM and ranking by the old method of modern portfolio theory. Moreover, a weak correlation was observed between the two approaches.

Abdel-Basset et al. (2020) used MCDM methods to evaluate the financial performance of 10 steel companies in Egypt, reporting that the companies were of nearly similar ranks. Yang et al. (2019) evaluated the performance of the top 55 technology companies in Taiwan using the three main criteria of solvency ratios, operating ability ratios, and profitability ratios, as well as 21 sub-criteria. They firstly applied the GRA method to assess the correlation between the criteria. Subsequently, they used the DEMATEL method to create the system's structural model, the ANP method for weighting the criteria, and the TOPSIS method for ranking. They highlighted that their results could be used as a reference by financial authorities in promoting green investment policies and as a criterion by investors in decision-making.

Saini and Khanduja (2019) evaluated the performance of 14 banks in India from 2017 to 2018 by using AHP and TOPSIS methods, concluding that these methods could be used effectively to assess the performance of them. Alinezhad and Alinia (2019) evaluated the performance of the companies from three petrochemical, pharmaceutical, and automotive industries in the Iranian capital market by using the eight criteria of current ratio, quick ratio, ROA, ROE, asset turnover ratio, capital turnover ratio, debt ratio, and debt to equity ratio from 2011 to 2016. They used the AHP method for ranking. The results showed that financial ratios are crucial and effective indicators in

evaluating the companies' performance, especially those in the automotive industry.

Raikar (2018) highlighted the importance of the cement industry in India and investigated the decline in India's cement production due to factors such as the slump in housing demand, the outflow of currency, and the imposition of taxes on housing from 2009 to 2016. He then evaluated the performance of 15 cement companies on the Indian Stock Exchange by using seven main criteria and ratios, including shareholders fund, investment valuation ratios, profitability ratios, liquidity and solvency ratios, debt coverage ratios, management efficiency ratios, and cash-flow indicators as well as 15 sub-criteria during the years 2013 to 2017. According to experts' opinions, he did the weighting using the AHP and the VIKOR methods to rank the companies. He also pointed out the effectiveness of the results depended on the decision-maker's mental evaluation. If the decision-maker was a beginner or inexperienced person, the best option was to weight the criteria using methods such as Entropy, CRITIC, etc. Likewise, if the decision-making were complex, it would be better to employ equal weights for all criteria.

Fathi et al. (2017) selected a stock portfolio out of 30 companies from 13 different industries on the Tehran Stock Exchange using the five main criteria of profitability ratios, growth ratios, market ratios, risk ratios, and liquidity ratios, as well as 16 sub-criteria. They proposed a combined model based on Fuzzy prioritization and COPRAS methods from 2011 to 2014. Based on the research background and expert opinion, they determined different financial criteria in selecting the portfolio and weighted the criteria using the fuzzy method. They ranked the companies utilizing the COPRAS method and eventually compared results with the TOPSIS ranking results. The results revealed that ranking with the COPRAS method differed from ranking with the TOPSIS method. Namazi and Namazi (2016) evaluated the performance of 142 companies on the Tehran Stock Exchange by using the criteria of traditional, modern, and economic value ratios during a 13-year period (from 2001 to 2013). The studied companies were weighted individually based on each financial metric with Shannon's Entropy method. They were also ranked using the TOPSIS method, and the final ranking was performed based on the aggregation of the ratios. The study results indicated that the TOPSIS method was suitable for ranking companies.

Moreover, modern financial ratios and economic value ratios were significantly correlated, but neither was significantly related to traditional ratios.

Reviewing the history of research conducted in this field reveals that these studies differ in various ways. The first distinction is the different industries studied by each survey. In addition, there are differences in the methods used to weight the criteria, the methods used to rank the options (studied companies), and the criteria used to rank the companies.

This study evaluates the performance of food and beverage companies as this industry holds a prominent position in the country and even in the region. We require performance evaluation to compare the companies, clarify their performance, and select the best companies. As a result, several criteria that have been used in evaluating the performance and ranking of companies in various studies were examined based on an in-depth review of the literature. The five financial criteria of profit margin, ROE, ROA, annual return, and annual standard deviation were selected as risk criteria based on expert opinion and their higher frequency in the literature. Moreover, the Bayesian Best-Worst Method, as a new MCDM method, was utilized for weighting the companies of this industry. Indeed, BWM was selected due to the weaknesses of other weighting methods, such as the presence of more comparative data and less stable comparisons due to relative valuation and more subjectivity in AHP and ANP methods. Other drawbacks include disregarding the importance of the criteria in Shannon and CRITIC entropy methods, undefined logarithm of negative numbers of normal matrices in Shannon entropy, and lacking a mechanism with strong mathematical logic to aggregate expert opinions in the BWM method, among others. The rankings yielded by CoCoSo and MARCOS methods were also compared in the current study.

3. Methodology

Bayesian Best-Worst Method (BWM)

Despite the advantages mentioned for the linear and nonlinear primitive models of BWM, this method has one major drawback: the absence of a mechanism with strong mathematical logic to consolidate multi-expert perspectives on a decision-making problem. Mohammadi and Rezaei (2020) created the Bayesian

BWM to enhance the effectiveness of the weights resulting from the multi-indicator decision-making problem in terms of integrating multiple expert opinions.

Suppose in a decision-making problem, k is the decision-maker $k = 1, 2, \dots, k$, n is the evaluation criterion of $c_j = c_1, c_2, \dots, c_n$. A_B^k denotes the comparison preference vector of the best criterion with other criteria from the perspective of the k th decision-maker, and A_W^k expresses the comparison preference vector of other criteria to the worst criterion of this decision-maker. If the optimal weight of the decision-maker k is equal to w^k , the optimal group weight of the problem criteria after aggregation equals w^{agg} . $A_B^{1:k}$ denotes the preference comparison vector of the best criterion to other criteria of all decision-makers, and $A_W^{1:k}$ represents the preference comparison vector of other criteria to their worst criterion. Accordingly, the equation of joint probability distribution of group decision-making in this method is as Equation (1):

$$P(w^{agg}, w^{1:k} | A_B^{1:k}, A_W^{1:k}) \tag{Equation (1)}$$

If the above equation is calculated, the probability law of Equation (2) can be used to calculate the probability of each person's variable:

$$P(x) = \sum_y p(x, y) \tag{Equation (2)}$$

where x and y are random variables.

The next step is to calculate optimal group weights. The optimal group weight w^{agg} depends on the optimal weight of each decision-maker. The equation used to calculate joint probability distribution in Bayesian BWM is as Equation (3):

$$P(w^{agg}, w^{1:k} | A_B^{1:k}, A_W^{1:k}) \propto P(A_B^{1:k}, A_W^{1:k} | w^{agg}, w^{1:k}) P(w^{agg}, w^{1:k}) \tag{Equation (3)}$$

By rewriting Equation (3), Equation (4) can be obtained:

$$P(A_B^{1:k}, A_W^{1:k} | w^{agg}, w^{1:k}) P(w^{agg}, w^{1:k}) = P(w^{agg}) \prod_{k=1}^k P(A_W^k | w^k) P(A_B^k | w^k) P(w^k | w^{agg}) \tag{Equation (4)}$$

In Equation (4), probability can be calculated by specifying the probability distribution of each element of the equation. The probability distribution $(A_W^k | w^k)$ and $(A_B^k | w^k)$ is a polynomial distribution, as described in Equation (5):

$$(A_B^k | w^k) \sim \text{multinomial}\left(\frac{1}{w^k}\right); (A_W^k | w^k) \sim \text{multinomial}(w^k), \forall k = 1, 2, \dots, k.$$

Also, the probability distribution w^k with condition w^{agg} is a Dirichlet distribution, as described in Equation (6):

$$w^k | w^{agg} \sim \text{Dir}(\gamma \times w^{agg}), \forall k = 1, 2, \dots, k. \tag{Equation (6)}$$

In this distribution, w^{agg} is the mean of distribution values, and γ is the negative parameter that follows the gamma distribution as in Equation (7):

$$\gamma \sim \text{gamma}(a, b), \tag{Equation (7)}$$

where a and b are the shape and scale of the distribution parameter, respectively. In order to reduce their impact on the final result, the values of these two parameters are considered 0.1 (continuous probability distribution). After finalizing the probability distribution of all parameters, the posterior probability distribution is calculated using the Monte Carlo Markov chain.

Another advantage of this version of the Best-Worst Method is that it calculates the confidence level of the factors' ranking. After calculating the weights of the compatibility factors, the results should be checked. This is achieved by calculating the confidence level in the ranking of factors. Suppose C_i and C_j are two criteria from the set of the problem criteria. The probability of C_i being better than C_j is as follows:

$$P(C_i > C_j) = \int I_{(w_i^{agg} > w_j^{agg})} P(W^{agg}) \tag{Equation (8)}$$

In this equation, W^{agg} is the operating group weight; $P(W^{agg})$ is the posterior probability of W^{agg} ; and I is the condition parameter that can be calculated when $W_i^{agg} > W_j^{agg}$, otherwise, the value of this parameter is zero. The Monte Carlo Markov chain is utilized to

perform multiple simulations, and the number of samples (Q) calculated by it is used to compute the mean of the confidence level:

Equation (9)

$$P(C_i > C_j) = \frac{1}{Q} Q = \frac{1}{Q} \sum_{q=1}^Q I(W_i^{aggq} > W_j^{aggq}),$$

$$P(C_j > C_i) = \frac{1}{Q} \sum_{q=1}^Q I(W_j^{aggq} > W_i^{aggq})$$

where, W^{aggq} is equal to the number q instance of the samples from W^{agg} . When $P(C_i > C_j) > 0.5$, it indicates that the number i factor is more important than the number j factor. This probability is the very same confidence level. Moreover, the total probability is equal to 1, as described in Equation (10) (Mohammadi and Rezaei, 2020):

Equation (10)

$$P(C_i > C_j) + P(C_j > C_i) = 1$$

CoCoSo Method

The CoCoSo method is one of the new MCDM techniques proposed by Yazdani et al., in 2018. In this method, a combined compromise solution is presented for ranking options.

Step 1. Developing a decision matrix

$$x_{ij} = \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2n} \\ \dots & \dots & \dots & \dots \\ x_{m1} & x_{m2} & \dots & x_{mn} \end{bmatrix}; i = 1, 2, \dots, m; j =$$

1, 2, ..., n. Equation (11)

Step 2. The normalization of the criteria values is performed based on the compromise normalization equation as in Equations (12) and (13).

$$r_{ij} = \frac{x_{ij} - \min_i x_{ij}}{\max_i x_{ij} - \min_i x_{ij}}; \text{ for benefit criterion}$$

Equation (12)

$$r_{ij} = \frac{\max_i x_{ij} - x_{ij}}{\max_i x_{ij} - \min_i x_{ij}}; \text{ for cost criterion}$$

Equation (13)

Third 3. The extraction of the balanced matrix (weighted sum method (WSM)) based on the normalized matrix multiplied by weight and the extraction of the rhythmic matrix (weighted product

method (WPM)) based on the normalized matrix to the power of weight

$$S_i = \sum_{j=1}^n (w_j r_{ij}) \quad \text{Equation (14)}$$

$$P_i = \sum_{j=1}^n (r_{ij})^{w_j} \quad \text{Equation (15)}$$

Step 4. The relative weight of the options is calculated by the aggregation of the given strategies. In this step, three score-evaluator strategies are used for the relative weights of other options.

$$k_{ia} = \frac{P_i + S_i}{\sum_{i=1}^m (P_i + S_i)} \quad \text{Equation (16)}$$

$$k_{ib} = \frac{P_i}{\min P_i} + \frac{S_i}{\min S_i} \quad \text{Equation (17)}$$

$$k_{ic} = \frac{\lambda(S_i) + (1-\lambda)(P_i)}{\lambda \max S_i + (1-\lambda) \max P_i}; \quad 0 \leq \lambda \leq 1$$

Equation (18)

Equation (16) expresses the arithmetic mean of the values P and S . Equation (17) performs the summation of the best options in the options. Equation (18) is a compromise between S and P . In this equation, λ is determined by the decision-maker, but in the 0.5 mode, it has a lot of flexibility.

Step 5. The final ranking of the options is determined based on K_i values (Yazdani et al., 2018).

$$K_i = (k_{ia} k_{ib} k_{ic})^{\frac{1}{3}} + \frac{1}{3} (k_{ia} + k_{ib} + k_{ic})$$

Equation (19)

MARCOS Method

MARCOS method is one of the new methods of MCDM, which measures and ranks the options based on the compromise solution. This method is used to rank the research options.

Step 1. The initial decision matrix consists of n criteria and m options.

Step 2. Developing an extensive initial decision matrix. At this stage, by adding ideal solution and anti-ideal solution to the initial decision matrix, a broad initial decision matrix is obtained.

Equation (20)

		C_1	C_2	\dots	C_n
$X =$	AAI	x_{aa1}	x_{aa2}	\dots	x_{aan}
	T_1	x_{11}	x_{12}	\dots	x_{1n}
	T_2	x_{21}	x_{22}	\dots	x_{2n}
	\dots	\dots	\dots	\dots	\dots
	T_m	x_{m1}	x_{m2}	\dots	x_{mn}
	AI	x_{ai1}	x_{ai2}	\dots	x_{ain}

The anti-ideal solution (AAI) is the worst value, and the ideal solution (AI) is the best value among the options, which is defined considering the nature of the criteria as per Equations (21) and (22):

$$AAI = \begin{matrix} \text{Min}_i x_{ij} & \text{if } j \in B & \text{and} & \text{Max}_i x_{ij} & \text{if } j \in C \end{matrix} \quad \text{Equation (21)}$$

$$AI = \begin{matrix} \text{Max}_i x_{ij} & \text{if } j \in B & \text{and} & \text{Min}_i x_{ij} & \text{if } j \in C \end{matrix} \quad \text{Equation (22)}$$

where B is the benefit criterion and C is the cost criterion.

Step 3. Normalizing the extensive initial decision matrix. The properties of Matrix $N = [n_{ij}]_{m \times n}$ is obtained from Equations (23) and (24):

$$n_{ij} = \frac{x_{ai}}{x_{ij}} \quad \text{if } j \in C \quad \text{Equation (23)}$$

$$n_{ij} = \frac{x_{ij}}{x_{ai}} \quad \text{if } j \in B \quad \text{Equation (24)}$$

where x_{ai} and x_{ij} are related to Matrix X .

Step 4. Developing the normal weight matrix $V = [v_{ij}]_{m \times n}$. At this stage, the weights of the criteria are multiplied in the normal matrix to obtain the balanced matrix:

$$V_{ij} = n_{ij} \times w_j \quad \text{Equation (25)}$$

Step 5: Calculating the degree of desirability of the options. In this part, the ideal degree of desirability (K^+) and the anti-ideal degree of desirability (k^-) of the options are calculated:

$$K_i^+ = \frac{S_i}{S_{ai}} \quad \text{Equation (26)}$$

$$K_i^- = \frac{S_i}{S_{aai}} \quad \text{Equation (27)}$$

In the above equations, S_i ($i = 1, 2, \dots, m$) is the sum of the values of each row in the balanced matrix, which is obtained by Equation (28):

$$S_i = \sum_{j=1}^n v_{ij} \quad \text{Equation (28)}$$

Step 6. Determining the optimal performance of the options. The function of compromise desirability of the observed options is related to the ideal and anti-

ideal solutions. In this part, the optimal performance of each option is calculated.

$$f(K_i) = \frac{K_i^+ + K_i^-}{1 + \frac{1-f(K_i^+)}{f(K_i^+)} + \frac{1-f(K_i^-)}{f(K_i^-)}} \quad \text{Equation (29)}$$

In the above equation, $f(K^-)$ is the anti-ideal desirability performance, and $f(K^+)$ is the ideal desirability performance of each option, which are calculated by Equations (30) and (31):

$$f(K_i^-) = \frac{K_i^+}{K_i^+ + K_i^-} \quad \text{Equation (30)}$$

$$f(K_i^+) = \frac{K_i^-}{K_i^+ + K_i^-} \quad \text{Equation (31)}$$

Step 7. Ranking the options. In this part, rankings are performed using the optimal performance values of the options. The higher the optimal performance of an option is, the better its rank will be (Stević et al., 2020).

Borda and Copeland Methods

This method operates on the basis of the majority rule and compares the ranks of each pair discovered by other methods. In case the number of pairs in which option K is preferred over option L is greater than the number of pairs in which option L is preferred over option K , the state is denoted by M . However, if the option K outnumbered the option L , the circumstance is indicated by X . M_s signifies the number of "wins" in this scenario, while X_s symbolizes the number of losses. An M indicates that the option in its row has won over its column. In contrast, an X represents a win for the column option over the row option. The score for each option is determined by tallying its number of victories (the number of M_s in its row). Since M and X values are factored in the prioritization process of Copeland's method, it can be considered an improvement over Borda's method. In Copeland's method, the score given to each option is determined by subtracting the number of wins from the losses. The final scores are determined according to the following equation (Kiani et al., 2022):

$$T_i = \sum M_i - \sum X_i \quad \text{Equation (32)}$$

4. Results

The present study collected data pertaining to specific criteria for 14 companies on the Tehran Stock Exchange in the food and beverage industry from 2018 to 2020. The sample companies were selected based on the systematic elimination method, considering that their fiscal year ended on March 20 of each year, that they did not change their fiscal year during the research period, and that the selected criteria were available during the specified period. Four of the criteria used in this study were positive, in case of which the higher the criteria, the better for the companies. Moreover, one of the criteria was negative, and the lower the criterion declines, the better for the companies. The values of the final weights of the indices are presented in Table 1 using the Bayesian BWM. In this method, after calculating the weights of the criteria, the confidence level of factor ranking is calculated and drawn. Figure 1 depicts the confidence level of criteria ranking. These confidence levels indicate, to some extent, that the results of the weights obtained from the model implementation (Table 1) are

acceptable to experts regarding the importance of these criteria. As shown in Table 1, return, ROE, and risk are this study's the most important financial criteria. The criteria are arranged in descending order in Figure 1, and the lower a criterion, the lesser its relative importance. However, on the directional lines between the criteria, a number is inserted, indicating that from the experts' point of view, the degree of confidence of the criterion on the arrow tip is superior to that of the criterion on the arrow bottom. Besides, the return criterion is completely superior, with 100% confidence (1), to the profit margin criterion, indicating the complete agreement of the experts' opinions. However, the same criterion is preferable to ROE by 83%, the criterion of risk by 88%, and to ROA by 59%. The lowest degree of preference is the preference of ROA to profit margin, which is 58%.

Below, the companies are ranked using CoCoSo and MARCOS MCDM methods. Due to a large number of calculations, only the final results of the ranking are given in Table 2.

Table 1. Final weights of criteria

Weights obtained	Profit margin	Return on assets	Return on equity	Return	Risk
	0.0994	0.1040	0.2514	0.3054	0.2398

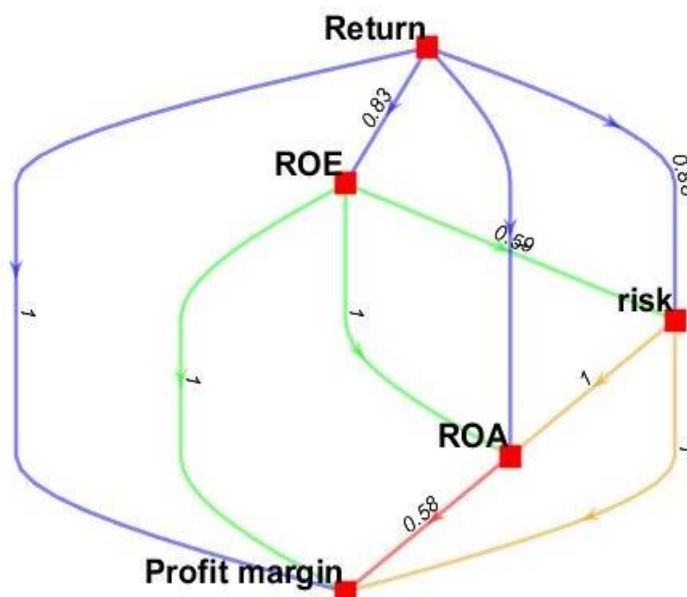


Figure 1. Confidence degrees of criteria preferences

Table 2. Ranking of companies using multi-criteria decision-making methods

Food and beverage companies	Ranks of companies by CoCoSo method			Ranks of companies by MARCOS method		
	2018	2019	2020	2018	2019	2020
Shahd Iran	5	1	11	2	1	11
Noosh Mazandaran	13	14	1	12	14	1
Piazar Agro-Industry	7	4	5	9	5	5
Behshahr Industries Development	3	11	4	5	10	3
Mahram, Iran	9	3	3	7	3	4
Pegah of Azerbaijan	12	12	10	13	12	10
Pegah of Isfahan	1	8	9	1	8	9
Pegah of Khorasan	6	2	13	6	2	13
Pak Dairy	14	13	8	14	13	6
Kalbar Dairy	10	10	6	10	11	7
Pars Minoo	8	6	12	8	6	12
Gorji biscuits	2	7	7	4	7	8
Salmin	4	5	14	3	4	14
Behnoush	11	9	2	11	9	2

According to Table 2, the ranking was performed by the two methods of CoCoSo and MARCOS for three years, from 2017 to 2019. The results reveal that the companies had almost varying rankings with respect to the methods used during these years. Considering the ranking of the companies by the mentioned methods for achieving the final ranking in each year, the Borda and Copeland methods were used to combine and integrate the above two MCDM methods. Table 3 reports the final ranking of food and beverage companies over these three years using the Borda and Copeland methods.

As can be seen, Table 3 presents the ranking results according to the studied criteria and the above

methods. In 2018, Isfahan Pegah Company was ranked first due to its high ROE and return; Salmin and Gorji Biscuits were ranked second and third, respectively. In 2019, Shahd Iran had the best performance for having the highest profit margin; the company had been ranked fifth the year before. Also, Pegah-e Khorasan and Mahram were second and third in the 2019 ranking. In 2020, Noosh-e Mazandaran was ranked first because of its highest return, ROE, ROA, and profit margin, showing a significant improvement compared to 2018 and 2019. Behnoosh and Mahram also took second and third places, respectively.

Table 3. Final rankings of food and beverage companies using the Borda and Copeland methods

Food and beverage companies	Ranking by Borda method			Ranking by Copeland method		
	2018	2019	2020	2018	2019	2020
Shahd Iran	5	1	11	5	1	11
Noosh Mazandaran	13	14	1	13	14	1
Piazar Agro-Industry	9	5	5	9	5	5
Behshahr Industries Development	4	11	4	4	11	4
Mahram, Iran	8	3	3	8	3	3
Pegah of Azerbaijan	12	12	10	12	12	10
Pegah of Isfahan	1	8	9	1	8	9
Pegah of Khorasan	6	2	13	6	2	13
Pak Dairy	14	13	8	14	13	8
Kalbar Dairy	10	10	6	10	10	6
Pars Minoo	7	6	12	7	6	12
Gorji biscuits	3	7	7	3	7	7
Salmin	2	4	14	2	4	14
Behnoush	11	9	2	11	9	2

5. Discussion and Conclusions

The performance evaluation process is one of the most important and complex processes in stock exchange companies. Nowadays, companies are faced with various methods for evaluating performance. Evaluating the obtained results and the model's efficacy to predict future performance can be a valuable step for companies in achieving their goals.

In the present study, the Bayesian BWM was used to weight the criteria and then to rank the food and beverage industry companies. The Bayesian BWM was utilized given its advantages, such as improving the effectiveness of weights resulting from MCDM in terms of consolidating expert opinions and calculating the confidence level of factor ranking. In doing so, first, five financial ratios were extracted based on the frequency of the financial ratios used in the research literature and based on expert opinion. In the next stage, the five financial criteria were calculated for the chosen companies from 2018 to 2020 using the available data in the companies' financial statements. Subsequently, as per the steps of the Bayesian BWM method for obtaining weights, eight financial experts were surveyed, and the weights of the criteria were calculated accordingly.

Furthermore, the present study assigns greater significance and weightage to Return and return on equity in comparison to other criteria. Numerous studies, including Rouhani rad et al. (2022), Lam et al. (2021), Vuković et al. (2020), Saini and Khanduja (2019), and Alinezhad and Alinia (2019), have employed such criteria to assess the performance of firms. Moreover, the confidence level of ranking by Bayesian BWM demonstrated that the return criterion was vastly superior to the profit margin criterion with a confidence of 1 (100 percent), indicating the complete agreement of the experts' opinions. Nevertheless, the return was preferable to ROE by 83%, to risk by 88%, and to ROA by 59%. The preference for the ROA criterion over the profit margin criterion was 58 percent less certain. Using the weights of the criteria and the calculated criteria for the companies, the CoCoSo and MARCOS methods ranked the companies in the subsequent step. The reason for combining multiple techniques is that each method belongs to a specific subset of MCDM compensation models and has its strengths and weaknesses; therefore, using the Borda and Copeland methods, it is possible to combine the results obtained

from multiple methods to achieve the final result. The rankings based on the selected criteria of this study for evaluating the financial performance indicated that the company rankings varied from year to year during the study period.

Considering the many criteria that can be used in evaluating the financial performance of companies, it is recommended that future researchers to use other criteria and other new MCDM methods. This will enable them to evaluate the performance of companies in a more comprehensive manner. In addition, it is recommended to incorporate financial metrics that have been comparatively underutilized in scholarly investigations. These alternative metrics may include simple Tobin's Q and standardized Tobin's Q, among others, as well as economic value indicators, such as economic value added (EVA) and free cash flows (FCF). The outcomes of these metrics should be juxtaposed with those of the traditional criteria. In addition to financial criteria, it is advisable for researchers to employ non-financial criteria in their studies. Furthermore, in prospective investigations, scholars may employ statistical methodologies such as factor analysis and principal component analysis to identify criteria. In subsequent research endeavors, scholars may employ the multi-criteria classification techniques posited in this investigation to scrutinize additional financial issues and assess the efficacy of investment funds and brokerage firms, among other entities.

Concerning the criteria used in the present study, which were among the financial ratios in evaluating the performance of companies, it is suggested that future research use other criteria, including other financial ratios, to examine the performance and ranking of companies in different industries. It might also be beneficial to research using other MCDM methods for weighting the criteria and ranking options individually or in combination.

References

- Abdel-Basset, M., Ding, W., Mohamed, R., & Metawa, N. (2020). An integrated plithogenic MCDM approach for financial performance evaluation of manufacturing industries. *Risk Management*, 22(3), 192-218.
- Aldalou, E., & Percin, S. (2020). Financial performance evaluation of food and drink index using fuzzy MCDM

- approach. *Uluslararası Ekonomi ve Yenilik Dergisi*, 6(1), 1-19.
- Aleemran, R., & Aleemran, S. (2013). Study the Effect of Government Tax Revenue on Stock Market in Iran. *Journal of Financial Economics (Financial Economics and Development)*, 7(23), 9-29. (In Persian)
- Alinezhad Ssarokolaei, M., & Alinia Esbokolaei, T. (2020). Financial Ranking of Petrochemical, Pharmaceutical and Automotive Companies Using Multi-Criteria Decision Making in Iranian Capital Market. *Journal of Financial Economics (Financial Economics and Development)*, 13(49), 237-256. (In Persian)
- Amado, C. A., Santos, S. P., & Marques, P. M. (2012). Integrating the Data Envelopment Analysis and the Balanced Scorecard approaches for enhanced performance assessment. *Omega*, 40(3), 390-403.
- Amiri M, Bamdadsoofi J, Mansouri mohammadabadi S. Provide a Model for Performance Evaluation of Decision Making Units by Using Common Weight Model of Data Envelopment Analysis Approach. *Journal of Operational Research and Its Applications*. 2018; 15 (1): 1-18. (In Persian)
- Asgharpour, M. J. (2008). Multi criteria decision making. Tehran, University of Tehran press (UTP). (In Persian)
- Carlucci, D. (2010). Evaluating and selecting key performance indicators: an ANP-based model. *Measuring business excellence*, 14(2), 66-76.
- Delen, D., Kuzey, C., & Uyar, A. (2013). Measuring firm performance using financial ratios: A decision tree approach. *Expert systems with applications*, 40(10), 3970-3983.
- Dror, S. (2008). The Balanced Scorecard versus quality award models as strategic frameworks. *Total Quality Management*, 19(6), 583-593.
- Fathi, M. R, Faraji, O., and Karimi Joughi, O. (2017). Presenting a Hybrid Model based on Fuzzy Prioritization Method and COPRAS for Portfolio Selection in Tehran Stock Exchange. *Financial Engineering and Portfolio Management*, 8(32), 129-149. (In Persian)
- Kiani, M., Bagheri, M., Ebrahimi, A., & Alimohammadlou, M. (2022). A model for prioritizing outsourceable activities in universities through an integrated fuzzy-MCDM method. *International Journal of Construction Management*, 22(5), 784-800.
- Lam, W. S., Lam, W. H., Jaaman, S. H., & Liew, K. F. (2021). Performance evaluation of construction companies using integrated entropy-fuzzy VIKOR model. *Entropy*, 23(3), 320.
- Liesz, T. J., & Maranville, S. J. (2008). Ratio Analysis featuring the Dupont Method: an overlooked topic in the finance module of small business management and entrepreneurship courses. *Small Business Institute Journal*, 1(1), 17-34.
- Lop, N. S., Ismail, K., Isa, H. M., & Khalil, N. (2018). An effective approach of performance measurement systems (PMS) for adoption in construction projects. *Journal of Engineering Science and Technology*, 13(12), 3951-3963.
- Mansouri, A., A., B. (2015). Evaluating the Financial Performance and Ranking the Pharmaceutical Companies Listed on the Tehran Stock Exchange by Using Hybrid Approaches of Fuzzy Analytic Hierarchy Process and VIKOR. *Journal of Health Accounting*, 4(3), 86-107. (In Persian)
- Mohammadi, M., & Rezaei, J. (2020). Bayesian best-worst method: A probabilistic group decision making model. *Omega*, 96, 102075.
- Namazi, M., Namazi, N. R. (2016). Ranking Firms Based on the Performance Evaluation Criteria via Multiple Attribute TOPSIS Technique and Comparing Evaluation Criteria (Evidence from Companies Listed in Tehran Stock Exchange). *Journal of Financial Accounting Research*, 8(2), 39-64. (In Persian)
- Neely, A., Gregory, M., & Platts, K. (2005). Performance measurement system design: A literature review and research agenda. *International journal of operations & production management*, 25(12), 1228-1263.
- Ou, Y. C. (2016). Using a hybrid decision-making model to evaluate the sustainable development performance of high-tech listed companies. *Journal of Business Economics and Management*, 17(3), 331-346.
- Raikar, A. V. (2018). An analytical study of the cement sector and selected cement companies in India by using multi criteria decision

- making (MCDM) technique of analytic hierarchy process (AHP) and VIKOR. *International Journal of Research in Management, Economics and Commerce*, 8(5), 1-11.
- Rouhani Rad, S., Akhavan Anvari, M. R., and Pakizeh, K. (2022). Ranking of Firms listed in Tehran Stock Exchange Using Multi Criteria Decision Making Methods (Case Study: Cement Industry Companies). *Financial Engineering and Portfolio Management*, 13(53), 72-90. (In Persain)
- Saini, N., & Khanduja, D. (2019). Financial performance evaluation using madm approaches in Indian banks. In *Advances in interdisciplinary engineering: Select Proceedings of FLAME 2018* (pp. 439-449). Springer, Singapore.
- Shaverdi, M., Ramezani, I., Tahmasebi, R., & Rostamy, A. A. A. (2016). Combining fuzzy AHP and fuzzy TOPSIS with financial ratios to design a novel performance evaluation model. *International Journal of Fuzzy Systems*, 18(2), 248-262.
- Stević, Ž., Pamučar, D., Puška, A., & Chatterjee, P. (2020). Sustainable supplier selection in healthcare industries using a new MCDM method: Measurement of alternatives and ranking according to COmpromise solution (MARCOS). *Computers & Industrial Engineering*, 140, 106231.
- Taticchi, P., & Balachandran, K. R. (2008). Forward performance measurement and management integrated frameworks. *International Journal of Accounting & Information Management*.
- Vaidya, O., & Chitnis, A. (2012). Performance evaluation in Indian corporate organizations: A survey. *Procedia-Social and Behavioral Sciences*, 37, 38-45.
- Vuković, M., Pivac, S., & Babić, Z. (2020). Comparative analysis of stock selection using a hybrid MCDM approach and modern portfolio theory. *Croatian Review of Economic, Business and Social Statistics*, 6(2), 58-68.
- Yang, C. C., Ou, S. L., & Hsu, L. C. (2019). A hybrid multi-criteria decision-making model for evaluating companies' green credit rating. *Sustainability*, 11(6), 1506.
- Yazdani, M., Zarate, P., Zavadskas, E. K., & Turskis, Z. (2018). A Combined Compromise Solution (CoCoSo) method for multi-criteria decision-making problems. *Management Decision*, 57(9), 2501-2519.
- Zeinoldini, S., & Karimi, M., & Khanzadi, A. (2020). Investigation the Effect of the Oil Price Shocks on the Stock Market Performance in Iran. *Journal of Financial Economics (Financial Economics and Development)*, 14(50), 145-169. (In Persain)

