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Supermarket performance measurement using hybrid multi-criteria decision-making methods

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A B S T R A C T

The supermarket sector is one of the most important components of the retail industry. Rapidly growing chain supermarkets stand out in this sector. This study introduces a hybrid method to assess the performance of stores within a supermarket chain. In the study, stores are compared over a five-year period using various criteria. These criteria include financial metrics such as rent cost, employee cost, energy cost, waste cost, supply cost, and sales revenue, as well as store size. Initially, the presence of differences between supermarkets based on these criteria was investigated. According to the criterion-based analysis, it is not easy to make a decision about the overall performance of supermarkets. Therefore, conducting the analysis using multi-criteria decision-making methods provides more meaningful results. In the proposed hybrid method, the criteria are first weighted using the entropy method to determine their importance levels. It was determined that the most important criterion is rent cost. The performance was then calculated using the VIKOR, MOORA, and ARAS methods. As a result of the analysis, the same store showed the best performance in all three methods.

1. Introduction

One of the most important components of the retail sector is the supermarket sector. With the increasing population and growing needs, combined with advancements in technology and rising demands, this sector continues to expand every day. The most important component of the supermarket sector is chain supermarkets. Chain supermarkets strive to be the best in a competitive environment, especially with changing economic conditions. Therefore, in order to better meet consumer demands, they must constantly engage in process improvement activities. This continuous need for improvement has led to the need for performance evaluation for supermarket chains (Mızrakçı, 2023).

Companies in the sector can determine their position in the industry through performance research. Yıldız (2013) stated that measuring performance would benefit the company in areas such as goal management, employee performance management, and resource management.

Numerous criteria can be used for performance measurements in a supermarket. First, these criteria need to be evaluated, and a decision must be made on which ones to use. In this complex process, multi-criteria decision-making (MCDM) methods are preferred in many studies to obtain more meaningful solutions and results. Özgüven (2011) examined the Migros, Carrefour, and Kipa hypermarkets, which ranked at the top of the Turkish supermarket sector according to a research list published by Ekonomist magazine in 2009. Five criteria affecting financial ratios were identified and these criteria were evaluated using the TOPSIS method, one of the MCDM techniques. Özbek (2016) used the Electre III method, one of the MCDM techniques, to measure the performance of the BIM chain supermarkets listed in Borsa Istanbul between 2008 and 2015. The years with high performance values were identified. Deste and Halifeoğlu (2019) evaluated the financial performance of five supermarkets listed on Borsa Istanbul in terms of supply chain management using the TOPSIS method and identified the supermarket with the best performance.

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Şenkal and Öztel (2020) examined the financial performance of Carrefoursa, a chain supermarket operating in Turkey's retail sector, between 2014 and 2018. During the evaluation, the weights of 12 financial ratios were calculated using the entropy method, and the performance rankings by year were determined using the COPRAS method. Budak and Sakarya (2022) assessed the impact of the COVID-19 pandemic on the financial performance of five companies listed in Borsa Istanbul. Using data from 2017-2022, they weighted the criteria with the entropy method and ranked the performances using the TOPSIS method. Batır (2022) conducted a similar study using the SWARA-assisted TOPSIS method to compare retail food companies listed on BIST.

When looking at research on supermarket performance measurement, it can be seen that not only MCDM methods are used. Data envelopment analysis (DEA) and statistical analysis are also among the methods used. Zeytinoğlu and Uydacı (2009) used the DEA method to measure the performance of stores within a supermarket chain and to assess the efficiency of stores. Erkorol (2009) identified the efficiency levels of 34 hypermarkets within a leading firm in the Turkish hypermarket sector using the DEA method.

Uluyol et al. (2011) investigated the effect of the relationship between employee satisfaction and customer satisfaction on supermarket performance. In the study, data were collected through a survey and the relationship factor analysis method was used for evaluation. Ateş (2014) examined the impact of perceived value and service quality of supermarket chains operating in the retail sector on their performance.

Khan et al. (2016) aimed to analyze the impact of inventory turnover on performance variables such as the percentage of profit margin and the sales surprise in a retail company in Hubei Province, China. The analysis revealed a negative relationship between inventory turnover and the percentage of profit margin, while a positive relationship was found between inventory turnover and sales surprise. De Waal et al. (2017) conducted a survey to determine the driving forces behind the success of a franchise supermarket. In this article, the authors introduce the High Performance Organization (HPO) framework, a validated technique, to assess companies' internal organizational strength and propose quality improvements. The purpose of the research was to test the applicability of the HPO framework in analyzing the strengths and performance of supermarkets and to provide improvement suggestions. A survey on supermarket success drivers was prepared and sent to 400 supermarket franchise owners, and the data collected was later analyzed. Supermarkets with good performance values were identified. Kazak (2018) evaluated the financial data of the BIM supermarket chain for the years 2011-2016 using a ratio analysis. As a result of the analysis, the strengths and weaknesses of the sector were revealed.

Luiz dos Santos and Vieira Marinho (2018) investigated the relationship between corporate-level entrepreneurial orientation, marketing capability, and business performance, which are generally studied independently, by formulating three hypotheses. They tested the precision of these hypotheses using statistical analysis methods. Kabuye et al. (2019) examined the contribution of internal control systems and working capital management to the financial performance of 110 supermarkets operating in Uganda. Broekmeulen and Van Donselaar (2019) conducted statistical analysis on the sales performance of three products in the fresh product department in 27 stores of three major retailers operating in Europe. Their goal was to reduce food waste, increase product freshness, and increase sales. As a result of the analysis, a complete expression was derived to quantify the freshness of the product, and an approach was developed and tested.

MCDM methods are used to help decision makers make more accurate choices (Dalbudak & Rençber, 2022). This study proposes a hybrid method, including MCDM techniques, to measure and evaluate the performance of three different stores within a supermarket chain. Various criteria have been identified based on expert opinions for the evaluation. The prepared multi-criteria dataset has been evaluated using the proposed hybrid method. The purpose of the study is to identify the store with the best performance among the three.

According to the proposed method, the entropy method was initially employed to determine the importance levels of the criteria, calculate their weights, and identify the most significant. Then, to evaluate the performance of supermarkets based on the weights of the identified criteria, the VIKOR, MOORA, and ARAS methods, which are commonly used in MCDM studies and have produced successful results, were applied. The results obtained from the three methods were compared.

Performance measurement studies for supermarket chains are generally conducted using financial ratios (such as current ratio, cash ratio, inventory turnover, net profit margin, etc.). In this study, performance is evaluated using different criteria, such as energy cost, waste cost, rent cost, employee cost, and store size.

2. Material and Methods

For businesses to be sustainable, they must generate profit. From this perspective, supermarkets also need to make a profit in order to achieve their commercial goals. In supermarket chains, operations must be monitored differently from a management perspective. As in many other sectors, there is intense competition in the supermarket industry. Under competitive conditions, profit margins tend to be lower. In such a situation, the performance monitoring of chain supermarkets becomes crucial.

In this study, the performance of three stores was compared based on various criteria. The evaluation criteria were identified through expert opinions from supermarket chain managers. These criteria include financial factors such as rent, employee, energy, waste, and supply costs, as well as sales revenue and store size. The dataset spans a five-year period and consists of monthly data collected from the three stores.

As shown in Fig. 1, the entropy method is applied first, followed by the VIKOR, MOORA, and ARAS methods. Shannon's entropy method is a commonly preferred method for criterion weighting in many studies and complex processes (Karami & Johansson, 2013; Ali et al., 2024).

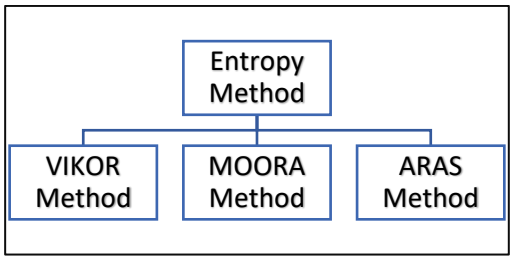

Fig. 1. Steps of the proposed method

2.1 Entropy Method

First, a decision matrix (A) is created to be used in all the methods. The decision matrix consists of the 'm' stores and the 't' criteria (Eq. (1)). Here, 'i' represents supermarkets, and 'j' represents selected evaluation criteria.

$$A = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1t} \\ a_{21} & a_{22} & \dots & a_{2t} \\ \vdots & \vdots & \dots & \vdots \\ a_{m1} & a_{m2} & \dots & a_{mt} \end{bmatrix} \quad (1)$$

In the entropy method, the criteria are first normalized (Eq. (2)). Then, the entropy values are calculated using Eq. (3). The uncertainty of the criterion is calculated using Eq. (4). A high value for this indicates that the corresponding criterion is important (İzgüden et al., 2022). Finally, the w_j values, which represent the criteria weights, are calculated (Eq. (5)). The calculated w_j values were used for the weighting of seven criteria in the VIKOR, MOORA, and ARAS methods in this study.

$$n_{ij} = \frac{a_{ij}}{\sum_{i=1}^{m} a_{ij}} \quad (2)$$

$$E_j = -\frac{1}{\ln m}\sum_{i=1}^{m}\left(n_{ij} \times \ln n_{ij}\right) \quad (3)$$

$$d_j = 1 - E_j \quad (4)$$

$$w_j = \frac{d_j}{\sum_{j=1}^{t} d_j} \quad (5)$$

2.2 VIKOR Method

The VIKOR method is a technique developed for solving complex problems with multiple criteria. The formulas used in the VIKOR method were initially developed by Yu (1973), followed by Zeleny and Cochrane (1982), and later used by Opricovic (1998) as a method for ranking alternatives (Sari, 2024).

In this method, the best (f_j^*) and worst (f_j^-) values of the criteria are initially determined (Kara & Baş, 2022). Then, the normalization of the decision matrix is performed. Unlike the entropy method, the normalization is done as shown in Eq. (6). In Eq. (7), the normalized and weighted V_{ij} matrix is obtained. The next step is to determine the sum of the weighted normalized criterion values (Eq. (8)) for each alternative and the largest of these values (Eq. (9)). In Eq. 10, the maximum and minimum values of S_i and R_i are identified. Finally, the ranking of the alternatives is determined by the Q_i values calculated in Eq. (11). The smallest Q_i value represents the best alternative. The q value in Eq. (11) ranges between [0, 1] and is a measure of the total utility of the criteria.

In the VIKOR method, whether the obtained ranking represents the best result depends on two conditions: the acceptable advantage and the acceptable stability conditions. Here, A^1 denotes the best solution, while A^2 denotes the second-best. The acceptable advantage condition is satisfied if the inequality in Eq. (12) holds. The acceptable stability condition is fulfilled if the top-ranked alternative also ranks first in at least one of the S_i or R_i values (Önder & Yıldırım, 2014).

$$r_{ij} = \frac{f_j^* - a_{ij}}{f_j^* - f_j^-} \tag{6}$$

$$V_{ij} = r_{ij} \times w_j \tag{7}$$

$$S_i = \sum_{j=1}^{t} V_{ij} \tag{8}$$

$$R_i = \max_{1 \le j \le t} V_{ij} \tag{9}$$

$$S^* = \min_{1 \le i \le m} S_i\,,\ S^- = \max_{1 \le i \le m} S_i\,,\ R^* = \min_{1 \le i \le m} R_i\,,\ R^- = \max_{1 \le i \le m} R_i \tag{10}$$

$$Q_i = \frac{q.(S_i - S^*)}{S^- - S^*} + \frac{(1-q).(R_i - R^*)}{R^- - R^*} \tag{11}$$

$$Q(A^2) - Q(A^1) \ge \frac{1}{i-1} \tag{12}$$

2.3 MOORA Method

The MOORA method is an MCDM technique developed by Brauers and Zavadskas (2006). It is a practical method widely preferred by researchers, and various versions are used.

First, the values in the decision matrix are normalized using Eq. (13). Then, the normalized values are weighted using Eq. (14). The criteria to maximize are ordered as *j*=1, 2, …, *k* while the criteria to minimize are ordered as j=k+1, k+2, …, t. The next step is to subtract the total weighted values of the minimized criteria from the total weighted values of the maximized criteria (Eq. (15)). Finally, by sorting the A_i values obtained in ascending order, the result is obtained, starting from the best alternative to the worst alternative.

$$\mathrm{a}_{ij}^* = \frac{\mathrm{a}_{ij}}{\sqrt{\sum_{\mathrm{j=1}}^{\mathrm{t}} \mathrm{a}_{ij}^2}} \tag{13}$$

$$M_{ij} = a_{ij} \times w_j \tag{14}$$

$$A_i = \sum_{j=1}^{k} M_{ij} - \sum_{j=k+1}^{t} M_{ij} \tag{15}$$

2.4 ARAS Method

The ARAS method is another widely preferred MCDM technique in the literature. It was developed by Zavadskas and Turskis (2010). This method not only determines the best alternative, but also reveals the proportional similarity of other alternatives to the best one. In the ARAS method, the criteria are weighted in such a way that their total weight is equal to 1, according to expert opinions. However, in this study, the weighting process was carried out using the weights obtained by the entropy method. The maximum values are selected for the benefit-type criteria, and the minimum values for the cost-type criteria are selected as the optimal values (Eq. (16), Eq. (17)). These selected values are added to the first row of the decision matrix (A) (Eq. 18). Then, the normalization and weighting processes are carried out. Normalization calculations are performed in two ways, depending on the benefit/cost nature of the criterion. For benefit-type criteria, the calculation in Eq. 19 is used, while for cost-type criteria, the calculations in Eq. (20) and then Eq. (21) are performed. This allows the process to proceed to the weighting step. The weighting of the criteria is done using Eq. (22). The total criterion value for each alternative is obtained using Eq. (23). The alternative with the highest value is the best choice. Finally, the proportional similarity of the alternatives to the best alternative is calculated using Eq. (24).

$$a_{0j} = \max_i a_{ij} \tag{16}$$

$$a_{0j} = \min_i a_{ij} \tag{17}$$

$$A = \begin{bmatrix} a_{01} & a_{02} & \dots & a_{0t} \\ a_{11} & a_{12} & \dots & a_{1t} \\ a_{21} & a_{22} & \dots & a_{2t} \\ \vdots & \vdots & \dots & \vdots \\ a_{m1} & a_{m2} & \dots & a_{mt} \end{bmatrix} \tag{18}$$

$$a_{ij}^{*} = \frac{a_{ij}}{\sum_{i=0}^{m} a_{ij}} \tag{19}$$

$$a_{ij}^{*} = \frac{1}{a_{ij}} \tag{20}$$

$$a_{ij}^{*} = \frac{a_{ij}^{*}}{\sum_{i=0}^{m} a_{ij}^{*}} \tag{21}$$

$$\bar{a}_{ij} = a_{ij}^{*} \times w_j \tag{22}$$

$$C_i = \sum_{j=1}^{t} \bar{a}_{ij} \tag{23}$$

$$P_i = \frac{C_i}{C_0} \tag{24}$$

3. Results & Discussion

In this study, the performance of three different stores in a supermarket chain was evaluated. The data necessary for the performance evaluation criteria, including rent cost, employee cost, energy cost, waste cost, supply cost, sales revenue, and store size, were prepared. The data cover a period of 5 years.

In this regard, the first step was to investigate whether there are differences in the criteria between supermarkets. The store size is fixed and does not change over time. In addition, the rent cost and the employee cost are criteria that vary annually. Therefore, no analysis was performed for these three criteria. When examining Figures 2-5 for the remaining four criteria, various observations can be made. However, it does not seem feasible to say that one store is better or worse than the others.

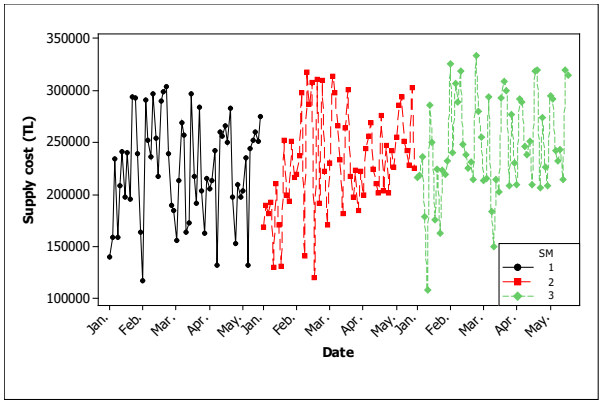

Fig. 2. Monthly supply costs

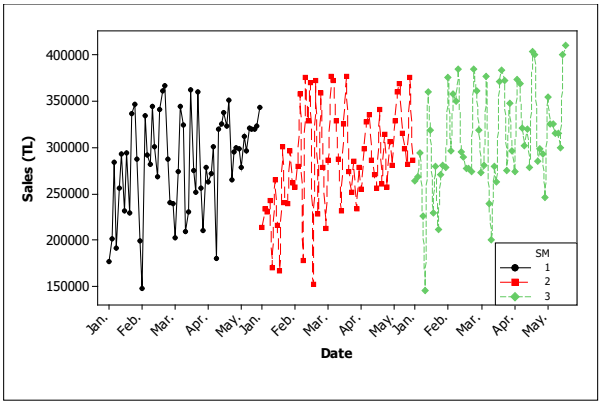

Fig. 3. Monthly sales

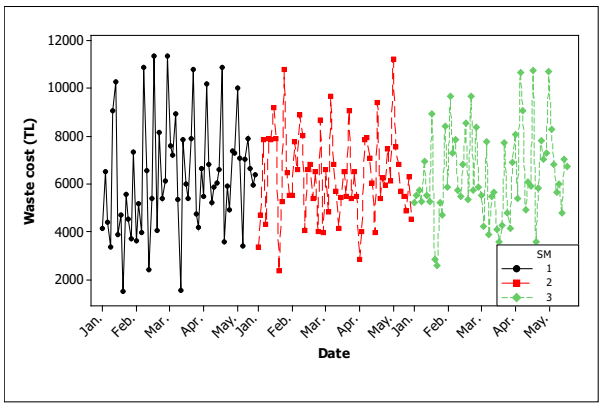

Fig. 4. Monthly waste costs

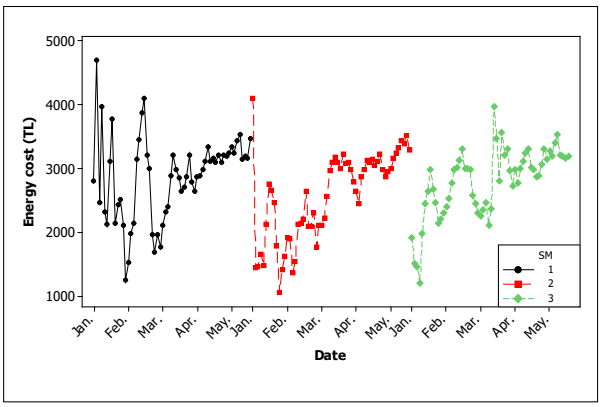

Fig. 5. Monthly energy costs

ANOVA was performed to determine whether there were differences between the stores for the criteria that varied monthly, including supply cost, sales revenue, waste cost, and energy cost. The results of the analysis, performed using Minitab software, are shown in Table 1. According to the results, there are differences in supply costs and sales revenue between the

stores, with Store 3 having higher supply costs and sales revenue. A statistically significant difference is also observed in energy costs, with Store 2 having lower energy costs. However, no statistically significant differences are found in waste costs.

Table 1

ANOVA results

Store	Avg. Supply cost	Avg. Sales revenue	Avg. Waste cost	Avg. Energy cost
1	224,076	284,557	6,295	2,877
2	230,469	285,884	6,340	2,584
3	245,979	309,183	6,342	2,804
p-value	**0.044**	**0.026**	**0.990**	**0.030**

Graphic and statistical analysis are insufficient to select a store. Therefore, it can be stated that the use of MCDM methods is necessary and meaningful. When evaluating with MCDM methods was started, a decision matrix was first created. The annual average values for the seven criteria of the three stores were used in the decision matrix. The decision matrix (a_{ij}) is shown in Table 2.

Table 2
Decision matrix

Store	Rent cost	Employee cost	Waste cost	Energy cost	Sales revenue	Supply cost	Store size
1	7.032	11.019	6.295	2.877	284.557	224.076	372
2	5.364	8.361	6.340	2.584	285.884	230.469	480
3	10.142	11.315	6.342	2.804	309.183	245.979	350

Then, the criteria weights were calculated using the entropy method. These weights are shown in Table 3.

Table 3
Weighted criteria

	Rent cost	Employee cost	Waste cost	Energy cost	Sales revenue	Supply cost	Store size
w_j	0,6192	0,1575	0,0001	0,0187	0,0133	0,0139	0,1772

When supermarkets were evaluated using weighted criteria with VIKOR, MOORA and ARAS methods, the results shown in Table 4 were obtained. The same ranking was achieved in all three methods. According to the results, the best performing supermarket is Store 2, followed by Store 1, and finally Store 3.

Table 4
Performance values of stores

Store	VIKOR		MOORA		ARAS	
	Rank	Performance value	Rank	Performance value	Rank	Performance value
1	2	0,5391	2	-0,3382	2	0,8114
2	1	0,0000	1	-0,2098	1	0,9977
3	3	1,0000	3	-0,4893	3	0,6786

4. Conclusions

Supermarket chains in the sector need to perform continuous performance evaluations by carefully planning every process from the supply stage to the product sales stage. Decision-making based on performance evaluations is crucial for managers. However, making decisions has become increasingly difficult under today's conditions.

In this study, a hybrid method incorporating MCDM techniques was proposed to compare supermarket performance. As a case study, performance evaluations were performed for three stores of a supermarket chain operating in the sector over a 5-year period. Based on expert opinions, the evaluation criteria were determined as rent cost, employee cost, waste cost, energy cost, supply cost, sales revenue, and store size. These criteria were initially statistically analyzed. According to these analyses, no store stood out.

The performance of the supermarket stores was then evaluated using the proposed hybrid MCDM methods. Criteria were weighted using the entropy method, which is one of the techniques used to make the best selection. According to the entropy method, the most important criterion was the rent cost, with a weight of 0.6192.

The performance of the three stores was evaluated using VIKOR, MOORA, and ARAS methods with the obtained criterion weights. The same rankings were obtained in all three evaluations. The supermarket with the best performance is Store 2. The fact that the same result was achieved with these three widely used methods in the literature supports the reliability of the methods. The importance of rent cost, which is the most significant criterion according to the weights, and Store 2's best performance in this criterion, played a crucial role in this supermarket securing the top rank.

At the end of this study, several other research ideas have emerged. Obtaining data can be challenging in such studies. However, if data can be obtained, it would be possible to compare more stores. The evaluation criteria could be further diversified. Competitive analyses could also be performed using these methods.

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