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Comparison of the Performances of MCDM Methods under Uncertainty: An Analysis on Bist SME Industry Index

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Abstract

MCDM is a sort of ranking and selection methodology widely used both in daily life and in disciplines such as social, science, health, informatics, and engineering. However, the selection of an appropriate MCDM method is a common and chronic problem of these disciplines. Because the issue of determining the most appropriate method among MCDM methods has not been clarified yet. Since the algorithms of more than a hundred MCDM methods currently that are in use are different, the ranking they produce or the "best alternative" often varies. Although all these methods claim to suggest the best alternative, it is unclear which method should be chosen for the decision maker. In fact, it can be said that input capabilities are focused more in the selection of MCDM methods. On the other hand, besides the potential capabilities of MCDM methods, the results they produce are also important in comparison. In this direction, MCDM-based financial performance measurement of companies was made in this study. The performance of WSA and FUCA methods was evaluated according to Spearman rho and entropy values. Accordingly, the method with the highest capacity is clearly FUCA, because this method showed a clearly higher performance in 10 of 12 problems/terms according to both criteria.

Keywords: *Performance of MCDMs, Multi Criteria Analysis, Share Price, Entropy, Financial Performance.*

Öz

Çok Kriterli Karar Verme (ÇKKV) hem günlük hayatta hem de sosyal, fen, sağlık, bilişim ve mühendislik gibi disiplinlerde yaygın olarak kullanılan bir tür sıralama ve seçme metodolojisidir. Ancak uygun bir ÇKKV yönteminin seçimi bu disiplinlerin ortak ve kronik bir problemidir. Çünkü ÇKKV yöntemleri içinde hangisinin en uygun yöntem olduğu konusu halen açıklığa kavuşturulamamıştır. Hali hazırda kullanılmakta olan yüzden fazla ÇKKV yönteminin algoritmaları farklı olduğu için ürettikleri sıralama ya da "en iyi alternatif" çoğu zaman değişkenlik göstemektedir. Yöntemlerin hepsi en iyi alternatifi kendilerinin önerdiğini iddia etse de karar verici için hangi yöntemin seçilmesi gerektiği belirsizdir. Esasen ÇKKV yöntemlerinin seçiminde daha çok girdi yetenekleri üzerine odaklanıldığı söylenebilir. Diğer taraftan, ÇKKV yöntemlerinin potansiyel yeteneklerinin yanında ürettikleri sonuçlar da karşılaştırmada önemlidir. Bu doğrultuda çalışmada firmaların ÇKKV bazlı finansal performans ölçümü yapılmıştır. Spearman rho ve entropy değerlerine göre WSA ve FUCA yöntemlerinin performansı değerlendirilmiştir. Buna göre kapasitesi en yüksek yöntem açık bir şekilde FUCA'dır, çünkü bu yöntem her iki ölçüte göre toplam 12 problemin/baz dönemin 10'unda net biçimde daha yüksek bir performans göstermiştir.

Anahtar Kelimeler: *ÇKKV'lerin Performansı, Çok Kriterli Analiz, Hisse Fiyatı, Entropi, Finansal Performans.*

Introduction

Financial performance evaluation of companies is a critical activity that affects the decisions of decision makers such as managers, shareholders, investors and policy makers. Measuring financial performance in an accurate framework is as important as measuring it. A company's multidimensional performance cannot be measured by a single criterion. It is useful to summarize all dimensions in a holistic evaluation system. This comprehensive approach is fully compatible with the MCDM paradigm. Therefore, the capabilities and solutions offered by MCDM methods have been used for financial performance measurement, in the past (Zopounidis and Doumpos, 2002; Diakoulaki, Mavrotas, and Papayannakis, 1995; Feng and Wang, 2000; Ertuğrul and Karakaşoğlu 2009; Pineda, Liou, Hsu, and Chuang, 2018; A. Ban, O. Ban, Bogdan, Popa, and Tuse, 2020).

With MCDM, an accurate consensus-based measure of financial performance is possible. However, due to the multidimensional nature of MCDM, an optimal solution does not seem possible, so the search for more accurate measurements still exists. In order to support this attempt, not only in the field of finance but also in other applied science fields, the need to improve or develop MCDM methods has arisen. Starting from the initial matrix that constitutes the MCDM procedure, continuous suggestions are made for data normalization, weighting techniques and especially the main calculation algorithm. Suggestions to improve the MCDM procedure are synonymous with improving the capabilities of the inputs. However, what it means to improve inputs or what effect it has on results has not been much commented on and discussed. The reason for this is obvious: there is a lack of objective criteria that is required to compare MCDM results.

In the literature, there are more than a hundred MCDM methods that can be recommended for analysis, but it is a difficult task to determine the most appropriate one is. For this reason, it is necessary to make a detailed examination and comparison of MCDM methods. Although some methods seem more appropriate under certain conditions and scenarios, there is no single method that can deal with all problems (Danesh, Ryan, and Abbasi, 2017). In general, MCDM method selection is a serious problem. Of course, the solution is difficult and uncertain (Triantaphyllou, 2000). Despite all this uncertainty and scarce opportunities, it is necessary to create an objective framework for the selection of MCDM. Developing at least an objective benchmark can be a positive step towards the start of this framework. Exploring the capacity of MCDM methods can be interesting and exciting. An evaluation can be made based on the final scores they produce. Here, the first thing is to determine the characteristics and unique tendencies of MCDM methods through evaluating the results they produce. In other words, the results produced by MCDM methods may bear traces of their identities. And if we can objectively identify that identity, it might be much easier to evaluate their characteristics.

The MCDM method capturing a better relationship with real life or a third arbitrator can be considered more successful. Baydaş and Elma (2021) and Baydaş and Eren (2021) base their studies on the share price as a third party representing real life. Accordingly, they compared the MCDM-based financial performance of companies with their simultaneous share price in the stock market, and found that there was a significant relationship between them. In the next stage, they only changed the MCDM methods, keeping the share price constant. And a remarkable interesting and original result was obtained. Both studies concluded that some MCDM methods predominantly produced higher correlations with share price. In other words, some MCDM methods clearly capture real life consistently better. This implies that there is something unique about the ranking results they produce. At the same time, these objective findings show that the hidden capacities of MCDM methods can be revealed. Moreover, this approach refers to a new key attempt as an introductory framework for the discussion of an automatic MCDM selection.

In this study, the MCDM method, which provides the relationship between financial performance and share price at a higher and stable manner, was determined and recommended to the decision maker. Moreover, a second criterion was proposed and confirmation was made with the first criterion. The objective information amount of the final scores produced by the MCDM methods were measured with the entropy criterion. The MCDM method, which has a higher amount of objective information, was considered to be more important and more capable.

The next part of the study covers literature review that is divided into three. First of all, opinions about the selection of MCDM methods will be discussed. In the next part, MCDM-based studies in the literature were examined in search of an appropriate financial performance. In particular, there are few studies investigating the relationship between share price and MCDM-based financial performance. The literature on different approaches to Entropy, which is the MCDM capacity measure that is recommended, was also reviewed. In the application part of the study, the financial performance scores of companies were calculated by using FUCA and WSA methods on the basis of 31 companies (alternative) and 5 ratios (criteria). The relationship between the final scores obtained and the share price was measured with Spearman Rho. FUCA and WSA were compared with the Rho criterion. Finally, the Entropy values of these methods were calculated and compared. In the discussion part of the study, the results of the comparison were evaluated.

Literature Review

In this part, approaches and research gap about the selection of an appropriate MCDM method were reviewed. Then, a few studies that use "the degree of correlation between the share price and financial performance of companies" as an objective alternative to the uncertainty in the choice of MCDM was evaluated. This unique approach may be important for determining the specific capacity of MCDM methods, because the nuance point that directly affects the correlation between the two variables in question is the MCDM method itself. Lastly, the significance and different uses of Entropy, which was used in this study for the first time as a MCDM performance comparison criterion, was evaluated, because it is considered to reveal the information content (amount) of MCDM methods in the literature.

Comparison of Objective Performance of MCDM Methods

The algorithms or calculation process of MCDM methods are designed to suggest the best alternative, but the best alternative can often differ according to the MCDM method that is used (Karaoğlan and Şahin, 2018). Different MCDM methods can produce inconsistent results in different problem scenarios, and applying the wrong methods to the wrong problem reduces the quality of the best alternative or ranking proposal (Wątróbski, Jankowski, Ziemba, Karczmarczyk, and Zioło, 2019). In this sense, it is vital to evaluate MCDM method alternatives appropriately. On the other hand, there is not yet a clear and generalizable consensus on selection of the most appropriate MCDM method for particular problem scenarios. According to Ozernoy (1992), there has never been a perfect MCDM method. In general, MCDM method selection is a serious problem and its solution is either difficult or uncertain (Triantaphyllou, 2000).

Each method has its own scope and performance characteristics (Kashid, Kashid, and Mehta, 2019). Although this may seem like the case, it may actually be possible to select an appropriate MCDM method by paying attention to some certain frameworks. Some MCDM methods are better applied to certain scenarios. It is beneficial to choose and apply a more appropriate MCDM method for certain problems (Danesh et al., 2017). Careful and accurate guidance is essential for the selection of an appropriate MCDM method. In this sense, a good expert guidance, who has mastered the technical details, can suggest an appropriate MCDM method according to the answers of decision maker for some questions, and by paying attention to the qualities that define the problem (Eldrandaly, Ahmed, and AbdelAziz, 2009). Although it is difficult to define the framework that best fits each decision maker's problems, it is an important procedure. At this point, all dimensions of the decision process, the role of the decision maker, the diversity of methods and available information should be taken into account (Mota, Campos, and Neves-Silva, 2012).

As can be seen from the above literature, many attempts have been made to define the MCDM framework that best fits each decision maker's problems. Recently, MCDM methods have started to be compared according to the ranking results they produce on the basis of outputs as an alternative to only inputs (Sałabun and Urbaniak, 2020). The development of the objective criteria for comparison of final results occurs very rarely in recent literature. In this context, the capacity and characteristics of MCDMs can be handled with a different and realistic approach. It can be thought that MCDM methods that are more related to real life may have a higher capacity. For example, according to Baydaş and Elma (2021), the dynamic relationship between the financial performance of companies that are measured by MCDM methods and their share prices offers an interesting and specific solution opportunity for solving the MCDM selection problem. Accordingly, when you change the MCDM methods, when the share price remains constant, the relationship increases or decreases.

It has been discovered that some MCDM methods consistently provide better statistical relationships between financial performance and share price of companies. These methods have at least a certain capacities. Therefore, these capacities are required to be confirmed by continuously iterative analysis. In this study, this approach was used as the first criterion. On the other hand, the category of objective evaluation method is used as a second criterion that can help in this regard. Although objective weighting methods are normally recommended for criterion weighting, they have also been proposed and used in the evaluation of normalized MCDM scores. For example, B. Zaidan, A. Zaidan, Abdul Karim, and Ahmad (2017) partially used the Standard Deviation method. Considering the final scores produced by MCDM techniques, it was determined that TOPSIS had the highest standard deviation value, while WSM had the lowest standard deviation value. In this study, it is suggested that MCDM results can be compared with the Entropy method. Thus, by applying the same weighting procedure, it can be revealed which MCDM method has more information. Similar to this first criterion, it can help to discover the special capacity of the MCDM methods. However, it is required to test these two criteria in other scenarios, so their claim can be concretely proven.

Financial Performance Measured by MCDM

Performance is an important indicator that reveals the extent to which a company has achieved its goals (Ayhan and Önder, 2021). MCDM methods are frequently used to summarize different and sometimes conflicting financial performance dimensions of enterprises with a single performance result (Diakoulaki et al., 1995). There is a search for an accurate measurement in the literature. And for this, different MCDM and weighting methods have been tried. In order to test the methods in different problem scenarios, performance measurements were created countless times by changing the country, sector, rate and time period constraints (Feng and Wang, 2000; Yükçü and Atağan, 2010; Yalçın, Bayrakdaroglu, and Kahraman, 2012; Tavana, Khalili-Damghani, and Rahmatian, 2015; Shen and Tzeng 2016; Karakul and Özaydın, 2019; Gümüş, Öziç and Sezer, 2019; Ban et al., 2020; Ağ ve Kuloğlu, 2020).

Although there are numerous MCDM-based financial performance studies, there is not much information about the selection of MCDM methods. In part, it appears that a choice may have been made on the assumption of strong mathematical abilities based on formulations of methods. On the other hand, the remarkable results of MCDM and financial performance measurement studies, which summarize the process from the distant past to the present, can be listed in general (De Almeida-Filho, De Lima Silva, and Ferreira, 2020). Firstly, the number of studies using MCDM methods is increasing rapidly. Secondly, AHP and TOPSIS methods are the two most widely used methods. Thirdly, ranking results of MCDM methods are generally similar statistically. Fourthly, profitability and risk factors are used as financial criteria. And finally, measurement of financial performance based on MCDM is one of the most studied topics in finance.

There unique study using the relationship between financial performance and return on stock to measure the capacity of MCDM methods belongs to Baydaş and Elma (2021). In this study, a strong and significant relationship was found between the share price and the financial performance rankings that are produced by MCDM methods. Then, it has been determined that PROMETHEE is the most appropriate method in financial performance analysis in terms of the results it produces. It is noteworthy that the return on share is proposed not as an investment proposal, but as a real-life reference solution/arbitrator to a methodological problem.

Exploring the Information Content of Final Scores of MCDMs: Entropy Approach

It is necessary to choose and adopt the most appropriate MCDM algorithm in order to evaluate the financial performance of companies comparatively. In this sense, the performances of MCDM methods should also be compared, but this is a difficult issue. Considering that different MCDM methods produce different scores, it would not be appropriate to compare them directly on the scores. To justify a reasonable comparison, the final ranking scores of the MCDM methods should be normalized. For MCDM techniques, the normalized score should be used to describe the closeness and difference in the curve model of each MCDM algorithm (Zaidan et al., 2017).

The category of objective assessment methods may be helpful in this regard. Objective weighting methods have also been used in the evaluation of normalized MCDM scores, although they are recommended for criterion weighting in general. For example, Zaidan et al. (2017) have used the standard deviation method partially. However, there is no any other example in this regard in the literature. On the other hand, Munier (2021) has an interesting suggestion in a social academic platform for researchers (www.researchgate.net). He suggests that entropy can be used to evaluate the ranking results produced by different types of fuzzy species. Thus, an insight can be obtained about which type of fuzzy to choose or which is better. In short, there is no any applied studies where the entropy of MCDM final scores is used as an objective benchmark for MCDM methods.

Basically, objective weight methods are mathematical estimations. They are built on a believed or assumed acceptance. It can be said that the greater the "difference between the values of each cell" in the criteria column, the more "valuable" the information contained in the criterion (indicator) for these methods. For instance, when all cell values in a criterion column are equal, the amount of information in that column is zero. In addition, criterion is not important in the evaluation and is worthless in this case. In other words, the weight of a criterion increases in direct proportion to the amount of information (Mukhametzyanov, 2021).

It is possible to evaluate methods like Entropy to discover the amount of information on the final scores of MCDMs. According to this objective approach, there is no formal or rational obstacle to calculate the entropy value of the final scores of MCDM methods. Therefore, entropy is suggested to be used in order to compare different MCDM methods. Thus, critical discussion issues such as the unique trends, performance, and capacity of MCDM methods and even the selection of the most appropriate MCDM method can be resolved objectively. On the other hand, according to the current classical understanding for any MCDM selection, this approach is a more objective and alternative solution under uncertainty.

In this study, Entropy approach was suggested for the first time to reveal the information content of the final scores of MCDM methods. In this direction, instead of detailed mathematical theoretical explanations, an evaluation directly on the data results was preferred. This situation is also appropriate for the “decision analytics” approach, which is one of the popular topics of today. Decision analytics is the science of using quantitative methods and technology to extract meaning or patterns from data to solve problems and make informed decisions (Tavana, 2021).

Decision analytics methods are used to understand what the facts are by analyzing historical data and drawing retrospective views about the past. Answering why something happened by measuring historical data with other data; using the findings to determine what will happen; and finally, answering the question of what to do by using the results can be counted as important stages of decision analytics. Similarly, in this study, it is investigated whether the rankings produced by MCDM methods have specific and significant patterns through Entropy method and Rho coefficient.

Research Methodology

In this study, first of all, performance measurement is made to compare the financial performances of companies by using different MCDM methods with a classical approach. Each financial ratio (criterion) represents a different objective (e.g., profit yield, risk and value generation). And they produce different information. However, using a single ratio does not allow for an overall assessment of the company's performance. For this reason, MCDM methods are frequently used in intercompany comparisons, because they can reflect the multidimensional performance of modern enterprises. MCDM methods are used to summarize different purposes of enterprises with a single performance system (Diakoulaki et al., 1995). In this sense, firstly, the final scores and rankings of companies are produced by measuring financial performance based on the equal weighting technique, and using FUCA (Faire Un Choix Adéqua) and WSA (Weighted Sum Approach) methods in terms of six financial ratios. According to the study of Baydaş, Elma and Pamučar, (2022), FUCA, which is used to measure financial performance, is the method with the highest, consistent and sustainable correlation with stock returns among the 10 MCDM methods. In addition, WSA was used for comparison purposes in this study, as it is one of the closest methods to the calculation method (simple weighted aggregation) used in daily life problems (university ranking, personnel selection, etc.).

In the next step, the use of two metrics with suggested validation mechanisms were focused for the determination of MCDM capacities: Rho coefficient and Entropy. Rho as the first criterion refers to a degree of statistical similarity with individual "return to share price" rankings of different rankings of financial performance obtained by different MCDM methods. The Spearman Rho coefficient measure is an indirect measure of MCDM capacity. In other words, the MCDM method, which produces the most significant and strongest correlation (Rho) with the share price among the alternatives, is suggested as the most capable and appropriate model for financial decision makers. The second criterion, entropy, is evaluated as follows. After the final scores of the MCDM methods are normalized, the Entropy values of each cluster are calculated. In the next step, the method with the highest amount of entropy information, which is calculated similarly to the entropy weighting procedure, was evaluated as more important or capable.

Performance Metrics

Although there are many ratios that represent the performance of companies, the number of representative ratios that can be used on critical issues such as risk, profitability and value creation is limited. In particular, the number of talented indicators that can establish a sustainable relationship with stock returns is less. Moreover, some ideal value demanding ratios such as current ratio, liquidity ratio, cash ratio, liabilities/equity ratio cannot be used directly in the MCDM procedure. Therefore, it is necessary to find meaningful, value-generating and suitable ratios that can be used for MCDM selection, and options are limited. In addition, MVA derivatives, and profitability ratios are more similar among themselves. But some ratios, although similar, do not have the same purpose and have different meanings. This indicates that they are useful for MCDM.

In this study, 5 performance criteria were determined to measure the financial performance of SME companies traded in BIST with two different MCDM methods to ensure comparability.

These criteria are ROE, ROA that refers to a company's profitability yield, MVA margin, MVA spread value generation, and Altman-Z that mostly refers to future risk although it has other capabilities. These criteria were calculated on a dynamic, not static basis, based on growth (change).

In the next step, different MCDM methods were compared with the share price return, which is a third and independent party, in order to compare the financial performance rankings obtained with these methods. The preferred technique for making this statistical comparison is Spearman's correlation, a type of rank correlation measurement. Thus, it was determined which MCDM method provides a better and stronger relationship with the share price.

Table 1 shows the objective MCDM benchmarks, performance criteria, and MCDM methods that are included in the study.

Table 1. MCDM Objective Comparison Methods, MCDM Methods and Performance Indicators in the Study

MCDM Benchmarks	MCDM Methods	Financial Performance Criteria
Entropy, Rho (Correlation with Share Return)	FUCA WSA	ALTMAN-Z SCORE, ROE, ROA, MVA Margin, MVA Spread

Market Value Added Margin (MVA Margin)

Considering that the most important goal of modern businesses is to maximize market value, it is critical to generate value. In this sense, MVA shows the difference between the market value of a company and the capital invested, which is the only indicator that clearly expresses the value production. MVA is used as a very important benchmarking tool to compare companies in terms of periodic value generation. MVA margin, on the other hand, is one of the MVA-based ratios that is derived to eliminate the scale (size) effect of companies in terms of MVA. It can be defined as the level of MVA that is created by sales. Like ROS, it measures the efficiency of sales but is based on the value produced, not the profit. It is desirable to increase this ratio, because it can be classified as a benefit-oriented indicator (Stewart, 2013).

Market Value Added Spread (MVA Spread)

As stated above, MVA represents value creation when market value exceeds the capital invested in the company by investors, whereas the opposite situation means that the company's values is eroded. For the use of MVA in the evaluation of companies, it is necessary to eliminate the size effect of companies. In other words, to ensure comparability, the ratio of MVA to invested capital is a solution, and this is expressed as the 'MVA spread' (Stewart, 2013). The 'MVA spread' ratio for financial performance shows the MVA that is generated by companies over their invested capital. In terms of efficiency, it shows how efficiently a company creates value, which is a benchmarking tool for those companies. An increase in the MVA spread is desirable, so it is a useful indicator.

Altman-Z Score

In an application by Altman (1968), Altman-Z Score was originally designed as a discriminant model that predicts financial distress, failure or bankruptcy. This model can be used in many ways not only to predict bankruptcy risk, but also to evaluate financial performance practices in the context of companies' relationship with success, risk and return on stock. According to Carton (2004), the exchange-based Altman-Z Score acts similarly to the stock return and is one of the ratios that best represents shareholder value in this respect. The Altman-Z score is an excellent all-round financial indicator. It is a benefit-oriented indicator since its increase is desired. It is useful to use this indicator in MCDM-based financial performance measurement studies, as it measures risk and uncertainty well. It is also essential to note that many ratios such as current ratio, cash ratio, liquidity ratio and foreign source/equity are not benefit/cost oriented, but they rather require ideal value. It is clear that the direct use of these ratios in the MCDM methods is mathematically problematic and risky.

Return on Equity (ROE)

The ROE ratio is widely used in the evaluation of company's performance. ROE measures the efficiency of net profit relative to equity. Thus, company partners gain important insight into whether their equity capital is being used optimally or not. On the other hand, investors get a comparative idea by looking at the rate of return they get from the capital they invest and the average of their competitors. ROE is defined as the ratio of net income to equity (Brigham and Houston, 2019). It is desirable for companies to increase ROE, and therefore this ratio is evaluated in MCDM approaches as a benefit-oriented criterion.

Return on Assets (ROA)

The ROA ratio is a classic type of ratio that has been used for a long time to analyze the financial performance of companies. It is another way of measuring profit efficiency. There is a nuance difference from ROE that ROA essentially reflects the company's indebtedness. It can be defined as a ratio showing the degree of effective use of assets (Brigham and Houston, 2019). Increasing ROA is a desirable ratio. And in this respect, it is also a benefit-oriented performance indicator for MCDM approaches.

The preferred financial indicators and formulations in this study can be seen in Table 2 below.

Table 2. Financial Indicators and Formulations in the Study

Indicators	Formulas	References
MVA Spread	MVA / Invested Capital	Stewart (2013)
MVA Margin	MVA / Sales	Stewart (2013)
ROE	Net Income / Common Equity	Brigham and Houstan (2019)
ROA	Net Income / Total Assets	Brigham and Houstan (2019)
ALTMAN-Z Score	1.2 (Working Capital / Total Assets) + 1.4 (Retained Earnings / Total Assets) + 3.3 (EBIT / Total Assets) + 0.6 (Market Value of Equity / Book Value of Total Liabilities) + 1.0 (Sales / Total Assets)	Carton (2004)
Share Price	(Closing Share Price – Initial Share Price) / Initial Share Price	*Carton (2004)*

MCDM Methods

In this study, primarily FUCA and WSA methods were used for a more accurate financial performance measurement. For FUCA, values in all criteria cells were converted to rank value in comparison. Even if the criteria are in different units, there is no need for normalization for the FUCA method. In this respect, it can be said that FUCA has an assumption or an indirect preference function. It has aspects similar to ORESTE or PROMETHEE. In a way, FUCA methodologically carries the characteristics of the European "outranking" school rather than the value or utility school. FUCA is a simple but highly efficient method. WSA, on the other hand, is a practical "simple weighted summation" method that is closest to daily life use. The only difference between WSA and the popular SAW method is the type of normalization that is used.

On the other hand, it can be said that the algorithm, equation or inputs of MCDM methods have been an effective reason for the adoption or selection of these methods. Of course, this basic calculation procedure is important in the development and selection of MCDM methods. However, it is essential to consider that the final results (scores of the alternatives), which are the outputs of the MCDM methods, are also important factors in comparing the methods. For example, the relation of outputs to real life or formally objective information potential is essential. Moreover, direct comparison with inputs is not possible, but these two directly imply MCDM capacity. The capacity determination thus opens the way for an objective benchmarking procedure that cannot be ignored for the next step for MCDM selection. Briefly, in this study, it was revealed which of the MCDM methods is more relevant to real life. In addition, insightful findings were obtained about which MCDM method has the highest amount of objective information. Consequently, the path to a suitable performance measurement seems to be related to the selection of an appropriate MCDM method. Therefore, this study makes an important contribution to the literature with its proposed objective MCDM selection framework.

FUCA (Faire Un Choix Adéquat)

This method is based on ranking the alternatives for each criterion. The first row has the best value, while the last row (n) is assigned the worst value. Then, the weighted sum of the values for each solution point is calculated and the solution with the smallest total value is the best chosen solution (Mendoza, Luis Fernando, Escobedo, Azzaro-Pantel, Pibouleau, Domenech, and Aguilar-Lasserre, 2011). The most important advantage of this method, which is relatively new and less known in the literature, is that it is simple and easy to calculate. The steps of the method can be explained as follows (Wang and Rangaiah, 2017):

Step 1: For each criterion, the best value is assigned as 1, and the worst value is assigned in the m row. If the criteria direction is maximization, the best value is the largest value in the column, otherwise the best value is the smallest value in the column.

Step 2: A weighted sum is calculated for each optimal solution. A weighted sum (i) is calculated for the solution of each alternative. Here, r_{ij} is the degree of solution i for target j. The solution with the smallest v_i is the suggested optimal solution (Wang and Rangaiah, 2017).

Table 3. Stages of FUCA Calculation

	FUCA
1	For each of the criteria values, 1 is assigned to the best value, m is assigned to the worst value.
2	Weighted Final Scores: $v_i = \sum_{j=1}^{n} (r_{ij} \times w_j)$

Source: *Wang and Rangaiah (2017)*

WSA (Weighted Sum Approach)

The weighted sum approach (WSA) is a method that aims to determine the option that provides the maximum benefit from the set of alternatives. This method is based on calculating the global use value of alternatives by taking into account the normalized criterion weights. It basically consists of two stages. These are normalization and determination of total utility (Taşabat, Cinemre, and Şen, 2015). It is the closest and simplest method to daily life use (WSM) with a few subjective limitations. If the units of measure are different, the criteria values are normalized and the total score of each alternative is obtained after summing according to the criteria weight. This method consists of the following two stages (Şen, 2014):

Step 1. Normalization of values

Here; i refers the rank of the alternative, j refers the rank of the criterion, yij refers the original value of the j criterion for alternative i, Hj is the maximum value of the j criterion representing the ideal option, and Dj is the minimum value of the alternative. Criterion j represents the ideal option. Accordingly, when the maximum benefit (Rij) is equal to 1, it is also obtained when the minimum benefit is 0.

Step 2. Calculation of the total benefit

At this stage, the utility value of each alternative is calculated. This is the sum of the normalized values that are multiplied by the specified criteria weights:

Table 4. Stages of WSA Calculation

Stages	WSA Calculation Process
1	Normalization of values: $r_{ij} = \frac{y_{ij} - D}{H_j - D_j}$
2	Calculation of the total benefit $u(a_i) = \sum_{j=1}^{k} r_{ij} . v_j$
3	Find the largest $u(a_i)$

Source: *Şen (2014)*

Benchmarks for MCDM Methods

This part covers bencmarks for MCDM methods that are Entrophy and Spearman Rho Coefficient.

Entropy Method

Information entropy, a measure of uncertainty, was first introduced by Shannon (1948). According to the idea of information entropy, which is widely used in many fields (Chen and Qu, 2006), the number or quality of information obtained from the decision-making environment is one of the accuracy and reliability determinants of the decision-making problem. Therefore, entropy is a very good measure when it is applied to different evaluation or evaluation situations in different decision making processes. Similarly, entropy can be used to measure the amount of useful information provided by the data itself (Wu, Sun, Liang, and Zha, 2011).

Entropy method can be considered in the context of the purpose of this study. The entropy weighting method is based on the amount of objective information about the criteria included in the decision matrix. The amount of this information is a parameter that can explain how important a criterion or ranking is. The smaller the value of entropy, the greater the weight based on entropy, so the more information the specific criterion provides. And that criterion or ranking set becomes so significant in the decision-making process (Li, Wang, Liu, Xin, Yang, and Gao, 2011). Entropy weighting method evaluates the ranking set by measuring the degree of differentiation between the values in the criterion ranking. The higher the dispersion degree of the measured rank, the higher its degree of differentiation, and more information can be obtained (Zhu, Tian, and Yan, 2020).

The main purpose of this study is to make a more accurate performance measurement. In this direction, the selection of an appropriate MCDM as very critical. Therefore, it is necessary to focus on MCDM results for a suitable MCDM selection. Entropy values of MCDM scores are the primary benchmark here.

As mentioned above, the Entropy method is based on a measure of uncertainty in information that is formulated with probability theory. If there is a large variation in the values of an objective among non-dominated solutions, a relatively higher weight is assigned to that objective. This method consists three steps (Wang, Parhi, Rangaiah, and Jana, 2020):

Step 1. Normalize the objective matrix with m rows (solutions) and n columns (targets) by applying sum normalization as is commonly used.

Step 2. Entropy is calculated for each criterion column.

Step 3. The weight of each target is determined.

Table 5. Stages of Entropy Method

Stages	Entropy Calculation Process
1	Normalize the objective matrix: $F_{ij} = \frac{f_{ij}}{\sum_{k=1}^{m} f_{kj}} \quad i \in \{1,2,\dots,m\};\ j \in \{1,2,\dots,n\}$
2	Calculate the Entropy of values of each objective: $E_j = -\frac{1}{\ln(m)} \sum_{i=1}^{m} (F_{ij} \ln F_{ij}) \quad j \in \{1,2,\dots,n\}$
3	Determine the weight for each objective: $w_j = \frac{1 - E_j}{\sum_{j=1}^{n}(1 - E_j)} \quad j \in \{1,2,\dots,n\}$

Source: *Wang et al. (2020)*

Spearman Rho Coefficient

The main purpose of this study is to make a more accurate performance measurement of MCDM methods. For this, the selection of an appropriate MCDM is considered to be critical. Thus, the focus was on MCDM results for a suitable MCDM selection. Entropy values of MCDM scores were the first benchmark as mentioned above. The second benchmark is the statistical correlation of MCDM results with real life or a third party. In this respect, MCDM-based financial performance results can be compared with real-life return results as a third party (arbitrator) (Baydaş and Elma, 2021; Baydaş and Eren, 2021; Baydaş et al., 2022).

The degree of similarity between two or more rankings is essential especially for the interpretation of comparisons. In this context, the degree of similarity of the rankings produced by the MCDM methods that are calculated for the same problem can be important. Moreover, a similar approach in the relationship with a third party, as in this study, is another matter of curiosity. Spearman's rank correlation coefficient, a widely used non-parametric measure of rank correlation coefficient, shows the statistical dependence of rank between two variables (Sałabun and Urbaniak, 2020). The calculation formula for this traditional data analysis tool is below:

$r_s = 1 - \frac{6 \sum di^2}{n\,(n^2 - 1)}$ Here r_s represents Spearman's Rho coefficient, while di represents the difference in binary rankings. And n represents the number of states in the formula.

In this study, the "Spearman Rho" similarity coefficient was used to compare the results of

MCDM methods. The correlation levels between MCDM-based financial performance results and the share price variable, which is a real-life example, were compared. Therefore, the success of the MCDM method, which provides the highest correlation with the third party in a stable and meaningful way, can be evaluated as a sign of talent or capacity.

Application

In this section, firstly, the data set and the experimental process were explained. Second, the findings and discussions were presented. Finally, the results of the application were evaluated.

Data Set and Experimental Process

For the purpose of the study, financial performance of 31 companies traded in the BIST-SME Industry Index in Turkey were measured on the basis of MCDM. As the decision criteria, five different performance indicators, which express profit efficiency, value generation and risk, were used. The period of the study is six years in total, including the years 2015-2020. The financial performances of the companies were calculated separately for each year/period.

In order to measure more accurate financial performance by choosing an appropriate MCDM method, this study consists of certain processes. First of all, the financial performances of the companies were calculated for each period with FUCA and WSA based MCDM methods. Then, the financial performance MCDM scores of the companies were compared in terms of both the percentage change of the share price, its relationship (rho) and the Entropy value. Thus, objective results were revealed for each period regarding the capacity, tendency, characteristics or significance of the MCDM method under a dual verification mechanism. These objective results proves that the most appropriate MCDM method is recommended depending on the performance success for those who want to evaluate the company's performance under certain constraints. In this study, FINNET data software was also used to obtain financial performance indicators and share price data.

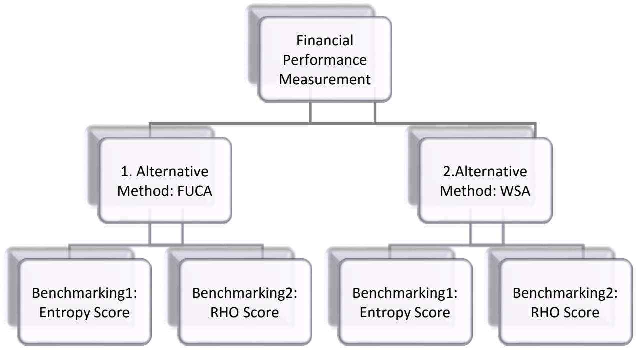

Figure 1. The Diagram of the Experimental Process

The flowchart of the study is simply shown in Figure 1. This chart follows the following steps.

Step 1: Preparation of Initial Decision Matrix

In order to calculate MCDMs, the criteria values obtained in the first step were placed in the decision matrix. Here, each of the five different ratio/indicator columns is a separate financial performance criterion. An initial decision matrix was created with these data for the MCDM calculation.

Step 2: Preparation of Weighted Decision Matrix

Equal weighting method was applied to all criteria.

Step 3: MCDM Calculation Operations

Microsoft Excel program was used to execute the MCDM process steps. A total of 12 different MCDM ranking results that belong to 31 companies were produced on the basis of six periods for two different MCDM methods. In other words, since a company's MCDM scores is calculated 12 times, it is possible to make more reliable and valid insights based on single-period MCDM results.

Step 4: Interpretation of MCDM Ranking Results

The correlation (Rho) between share price and financial performance were evaluated to understand which of the MCDM rankings yielded stronger results. In addition to this evaluation, for the first time in the literature, we proposed a second benchmark. Entropy analysis was performed to measure MCDM capacity with a structured procedure similar to objective weighting methods. For all these processes, MINITAB and Excel program were used together.

Step 5: Comparison of Performance Results of MCDM Methods

MCDM methods were compared against the Rho and Entropy benchmarks. As a result of separate calculations for these two criteria, it has been suggested that both the period-based method and the method with the best average may be more important or appropriate.

Considering that a MCDM model is primarily designed to solve real-life problems (Munier, 2006), it is appropriate to base the share prices of companies as an arbitrator (third party) (Baydaş and Eren, 2021; Baydaş and Elma, 2021). It also means that the underlying type of financial performance is compatible with the goal of shareholder value maximization. This type of performance metric is an attractive idea for decision makers. On the other hand, as a benchmark for determining the capacity of MCDMs, the amount of objective information (calculated by Entropy) of MCDM results may be appropriate as a second verification mechanism.

As it is known, MCDM methods come into play as a kind of decision support element in order to make quality and healthy decisions under uncertainty. The proposed selection procedure for the most appropriate MCDM method has potential to increase the accuracy of the decisions made. Because each MCDM method has different formulations and assumptions, so the results they produce are often different. The random choice of a MCDM method influences any decision. Therefore, the selection of an appropriate MCDM can directly affect the decisions in a positive way.

Findings and Results

There are more than a hundred MCDM methods in the literature, and all of them claim to suggest the best alternative. However, there is complete "uncertainty" about which is the best MCDM method. Most of the MCDM methods often produce different ranking results as they have different computational procedures. In fact, this feature shows that they have different and special features. The "Entropy" objective evaluation procedure that was recommended for weighting criteria in the normal procedure can also be used to determine the specific feature or capacity of MCDM scores. Secondly, the "Rho" coefficient level, which expresses the correlation between financial performance and share price (percentage change), can be suggested as another confirmatory criterion.

The results obtained with these suggested criteria (Entropy and Rho) are shown in the tables below. Final scores produced by FUCA and WSA methods were compared according to Entropy and Spearman Rho criteria. Spearman Rho and Entropy values that were calculated for six years periods between 2015 and 2020 show remarkable and unique results. Accordingly, it is clear that the MCDM method, which gives better results, is the FUCA for both criteria. These results clearly show that some MCDM methods have specific capacities. It can be said that the rankings that were produced by the FUCA and WSA methods have a very consistent and unique trend. Entropy value results show that FUCA has higher objective information content compared to WSA method. The Rho results similarly demonstrate that FUCA captures real life better. Thus, it has been more strongly confirmed that the FUCA method has a special capacity with a dual verification mechanism. Table 6 below shows the unnormalized MCDM scores.

Table 6. Unnormalized Final Scores of MCDM Methods in Six Period (2015-2020)

	2020	2020	2019	2019	2018	2018	2017	2017	2016	2016	2015	2015
	FUCA	WSA	FUCA	WSA	FUCA	WSA	FUCA	WSA	FUCA	WSA	FUCA	WSA
ACSEL	17.4	0.0987	15.8	0.3810	8.2	0.6522	22.4	0.3253	22.2	0.4115	10.2	0.5451
BLCYT	24.2	0.0409	10	0.4544	10.4	0.5848	11.8	0.4696	21	0.5028	12.8	0.4784
BRKSN	13.2	0.1451	23	0.3392	19.8	0.5380	20.6	0.4413	9	0.5744	19.4	0.4332
BURCE	17.4	0.1013	24.6	0.3267	11.8	0.5788	22.6	0.4167	10.2	0.5813	22.6	0.4088
BURVA	8.2	0.3286	10.4	0.5443	24	0.5216	10.6	0.5113	18.2	0.5216	11.8	0.4890
DAGI	22.2	0.0812	17	0.3904	22.8	0.5197	14.2	0.4579	25.4	0.4778	13.8	0.4468
DITAS	21	0.0905	20.8	0.3290	15	0.5769	6.4	0.5486	24	0.4907	26.2	0.3152

DOBUR	14.6	0.1707	20.2	0.3345	11.4	0.6097	12.2	0.4690	17.6	0.4415	17.2	0.4407
DOGUB	13.2	0.1212	14.2	0.4702	13.4	0.5583	13.6	0.4559	20.6	0.4288	7.8	0.6609
EMKEL	22	0.0832	13.4	0.4069	22.8	0.5125	23.2	0.3797	15.6	0.5557	11.4	0.4801
ERSU	17.2	0.0927	10.2	0.4803	22.4	0.5264	11.2	0.4695	12.8	0.5695	20.2	0.4247
FMIZP	10	0.2861	10.6	0.6369	6.6	0.7816	21.2	0.4430	19.6	0.3996	11.6	0.5061
FRIGO	22	0.0787	8.2	0.4311	8.2	0.5820	13.6	0.4892	9	0.6137	18.4	0.4053
GEDZA	13.4	0.1154	21	0.3433	12.4	0.5870	18	0.4534	6.4	0.6016	23.6	0.3963
IZFAS	16.4	0.1010	18.4	0.3790	29.6	0.4386	10.2	0.5963	13.4	0.5576	24	0.3611
IZTAR	12.2	0.1388	29	0.2525	7.2	0.5967	14	0.4579	13.6	0.5347	19.8	0.4268
LUKSK	21.8	0.0757	15.2	0.3960	13	0.5613	21.4	0.3498	10.2	0.6281	15	0.4600
MAKTK	19.2	0.0816	25.4	0.3298	17.2	0.5711	3.4	0.5967	10	0.6565	13	0.4802
MERKO	11.8	0.1900	12.8	0.4310	22.2	0.4412	20.8	0.3426	24.6	0.4790	20.4	0.3231
NIBAS	12	0.5437	10.4	0.5016	11.6	0.6461	19.2	0.4263	18.6	0.4762	18.8	0.4479
OYLUM	21.6	0.0863	11.2	0.4130	18.6	0.5695	21	0.4334	9.2	0.5699	16.2	0.4575
OZBAL	14	0.3476	20.2	0.3881	19.2	0.5055	21.6	0.3554	13.4	0.6282	10.8	0.4665
POLTK	7.4	0.2232	3	0.7386	13.2	0.6366	12.2	0.5223	23.4	0.4376	7	0.6330
PRZMA	20.8	0.1015	9.6	0.5651	18.4	0.5590	27.6	0.3020	7.8	0.6127	19.6	0.3594
RODRG	18.6	0.0831	21.2	0.3495	18.6	0.5688	18.8	0.4337	11.2	0.5631	6.2	0.5349
SAMAT	8.2	0.2263	23.2	0.2701	12.8	0.5671	18.4	0.4471	16.2	0.5217	12.6	0.4697
SANFM	19.4	0.0930	11.8	0.3892	16.8	0.5564	12	0.4671	10.2	0.6315	27.6	0.2959
SELGD	17.4	0.0912	18.6	0.3821	10.4	0.5716	10.8	0.4911	24.2	0.4532	9	0.5105
TMPOL	28.2	0.0445	10.4	0.4473	25.8	0.5221	23.4	0.3761	19.6	0.5092	7.8	0.6085
VANGD	4.2	0.3484	20.2	0.3038	21	0.3632	5.4	0.8147	18	0.4991	24.6	0.3217
YAPRK	6.8	0.2110	16	0.3688	11.2	0.5726	14.2	0.4504	20.8	0.5136	16.6	0.4591

Table 7 above shows normalized MCDM scores. In order to calculate the Entropy value of the scores produced by the MCDM methods, they should firstly be normalized.

Table 7. Normalized Final Scores of MCDM Methods in Six Period (2015-2020)

	2020	2020	2019	2019	2018	2018	2017	2017	2016	2016	2015	2015
	FUCA	**WSA**	**FUCA**	**WSA**	**FUCA**	**WSA**	**FUCA**	**WSA**	**FUCA**	**WSA**	**FUCA**	**WSA**
ACSEL	0.0351	0.0205	0.0319	0.0298	0.0165	0.0375	0.0452	0.0229	0.0448	0.0250	0.0206	0.0388
BLCYT	0.0488	0.0085	0.0202	0.0356	0.0210	0.0337	0.0238	0.0331	0.0423	0.0306	0.0258	0.0341
BRKSN	0.0266	0.0301	0.0464	0.0266	0.0399	0.0310	0.0415	0.0311	0.0181	0.0349	0.0391	0.0308
BURCE	0.0351	0.0210	0.0496	0.0256	0.0238	0.0333	0.0456	0.0294	0.0206	0.0354	0.0456	0.0291
BURVA	0.0165	0.0682	0.0210	0.0426	0.0484	0.0300	0.0214	0.0360	0.0367	0.0317	0.0238	0.0348
DAGI	0.0448	0.0168	0.0343	0.0306	0.0460	0.0299	0.0286	0.0323	0.0512	0.0291	0.0278	0.0318
DITAS	0.0423	0.0188	0.0419	0.0258	0.0302	0.0332	0.0129	0.0386	0.0484	0.0298	0.0528	0.0224
DOBUR	0.0294	0.0354	0.0407	0.0262	0.0230	0.0351	0.0246	0.0330	0.0355	0.0269	0.0347	0.0314
DOGUB	0.0266	0.0251	0.0286	0.0368	0.0270	0.0321	0.0274	0.0321	0.0415	0.0261	0.0157	0.0471
EMKEL	0.0444	0.0173	0.0270	0.0319	0.0460	0.0295	0.0468	0.0267	0.0315	0.0338	0.0230	0.0342
ERSU	0.0347	0.0192	0.0206	0.0376	0.0452	0.0303	0.0226	0.0331	0.0258	0.0346	0.0407	0.0302
FMIZP	0.0202	0.0593	0.0214	0.0499	0.0133	0.0450	0.0427	0.0312	0.0395	0.0243	0.0234	0.0360
FRIGO	0.0444	0.0163	0.0165	0.0337	0.0165	0.0335	0.0274	0.0345	0.0181	0.0373	0.0371	0.0289
GEDZA	0.0270	0.0239	0.0423	0.0269	0.0250	0.0338	0.0363	0.0319	0.0129	0.0366	0.0476	0.0282
IZFAS	0.0331	0.0209	0.0371	0.0297	0.0597	0.0252	0.0206	0.0420	0.0270	0.0339	0.0484	0.0257
IZTAR	0.0246	0.0288	0.0585	0.0198	0.0145	0.0343	0.0282	0.0323	0.0274	0.0325	0.0399	0.0304
LUKSK	0.0440	0.0157	0.0306	0.0310	0.0262	0.0323	0.0431	0.0246	0.0206	0.0382	0.0302	0.0327
MAKTK	0.0387	0.0169	0.0512	0.0258	0.0347	0.0329	0.0069	0.0420	0.0202	0.0399	0.0262	0.0342
MERKO	0.0238	0.0394	0.0258	0.0337	0.0448	0.0254	0.0419	0.0241	0.0496	0.0291	0.0411	0.0230
NIBAS	0.0242	0.1128	0.0210	0.0393	0.0234	0.0372	0.0387	0.0300	0.0375	0.0290	0.0379	0.0319
OYLUM	0.0435	0.0179	0.0226	0.0323	0.0375	0.0328	0.0423	0.0305	0.0185	0.0347	0.0327	0.0326
OZBAL	0.0282	0.0721	0.0407	0.0304	0.0387	0.0291	0.0435	0.0250	0.0270	0.0382	0.0218	0.0332
POLTK	0.0149	0.0463	0.0060	0.0578	0.0266	0.0366	0.0246	0.0368	0.0472	0.0266	0.0141	0.0451
PRZMA	0.0419	0.0211	0.0194	0.0442	0.0371	0.0322	0.0556	0.0213	0.0157	0.0373	0.0395	0.0256
RODRG	0.0375	0.0172	0.0427	0.0274	0.0375	0.0327	0.0379	0.0306	0.0226	0.0342	0.0125	0.0381
SAMAT	0.0165	0.0469	0.0468	0.0211	0.0258	0.0326	0.0371	0.0315	0.0327	0.0317	0.0254	0.0334
SANFM	0.0391	0.0193	0.0238	0.0305	0.0339	0.0320	0.0242	0.0329	0.0206	0.0384	0.0556	0.0211
SELGD	0.0351	0.0189	0.0375	0.0299	0.0210	0.0329	0.0218	0.0346	0.0488	0.0276	0.0181	0.0363
TMPOL	0.0569	0.0092	0.0210	0.0350	0.0520	0.0300	0.0472	0.0265	0.0395	0.0310	0.0157	0.0433
VANGD	0.0085	0.0723	0.0407	0.0238	0.0423	0.0209	0.0109	0.0574	0.0363	0.0304	0.0496	0.0229
YAPRK	0.0137	0.0438	0.0323	0.0289	0.0226	0.0330	0.0286	0.0317	0.0419	0.0312	0.0335	0.0327

Table 8 below shows the Entropy value (ej), 1-Entropy value (1-e) and final significance value (wj) of the MCDM methods. Accordingly, FUCA has a higher amount of information in all the remaining five years except 2020.

Table 8. Comparison Results for Significance Levels of FUCA and WSA by Entropy Values in Six Period (2015-2020)

	ej FUCA	**ej WSA**		**1-e FUCA**	**1-e WSA**		**wj FUCA**	**wj WSA**
2020	0.980086	0.939177	&	0.019914	0.060823	&	*0.246651*	***0.753349***
2019	0.978747	0.99167	&	0.021253	0.00833	&	***0.718416***	*0.281584*
2018	0.980277	0.997631	&	0.019723	0.002369	&	***0.892762***	*0.107238*
2017	0.978487	0.99419	&	0.021513	0.00581	&	***0.787359***	*0.212641*
2016	0.981152	0.997462	&	0.018848	0.002538	&	***0.881342***	*0.118658*
2015	0.979528	0.994776	&	0.020472	0.005224	&	***0.796691***	*0.203309*

It is clearly seen from the Table 8 that the Entropy significance level of the scores produced by the FUCA method is higher. Moreover, the average entropy significance value of FUCA for the other years except 2020 is almost double that of the other method.

The comparison results (wj) in Table 8 were calculated according to the following formula: (Value of Method 1-e/Value of Total 1-e). In this sense, it was confirmed that FUCA scores have a higher entropy significance value than WSA scores (Total) in all base periods. In other words, the information content of FUCA is higher.

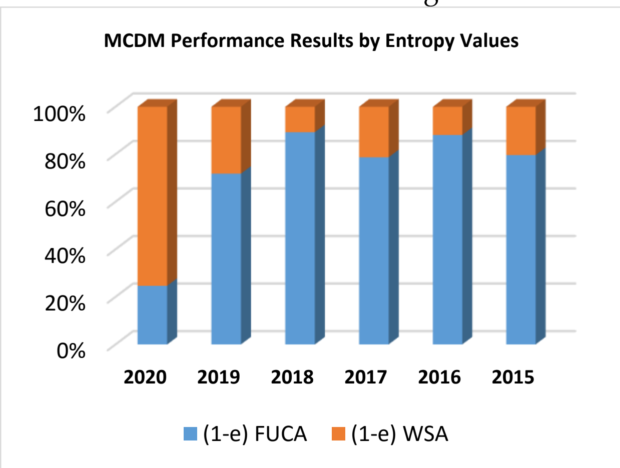

Figure 2. MCDM Comparison Results by Entropy Values in Six Period (2015-2020)

According to Figure 2, FUCA is higher than WSA scores in all base periods (except 2020).

Another criterion recommended to compare MCDM methods is the Rho coefficient, which expresses the degree of relation to real life. The statistical correlation results between MCDM-based financial performance and share price are shown in Table 9 below.

Table 9. MCDM Comparison Results by Spearman Rho Coefficient between FP and SR in Six Period (2015-2020)

	2020	**2019**	**2018**	**2017**	**2016**	**2015**	
	Rho	Rho	Rho	Rho	Rho	Rho	Rho Mean
FUCA	**0.581**	**0.603**	**0.743**	0.591	**0.639**	**0.455**	**0.602**
p-value	0.001	0.000	0.000	0.000	0.000	0.01	0.0018
WSA	0.55	0.456	0.642	**0.592**	0.384	0.323	0.4912
p-value	0.001	0.01	0.000	0.000	0.033	0.076	0.02

Table 9 displays that FUCA scores have higher Rho coefficients than WSA scores in other base periods, except for one base period (2017).

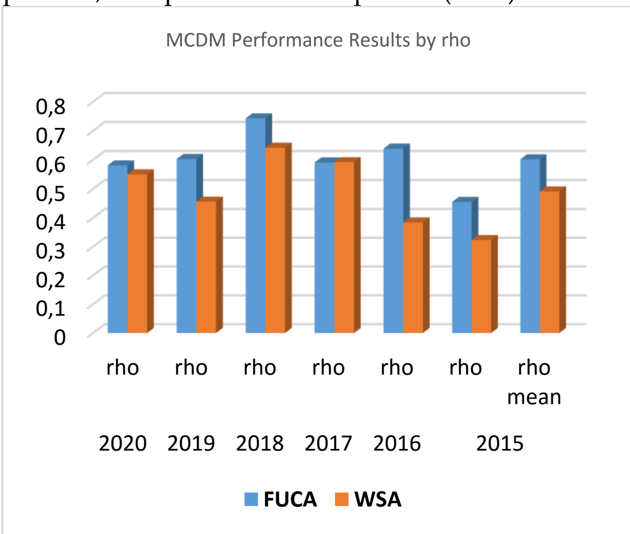

Figure 3. MCDM Comparison Results by Rho Values in Six Period (2015-2020)

According to Figure 3, FUCA scores have higher Rho coefficients than WSA scores in all base periods.

Table 10. Average Entropy Scores and RHO Coefficients According to FUCA and WSA Scores

Entropy (formal)	**MEAN**	**RANK**	**rho (actual)**	**MEAN**	**RANK**
FUCA	0.7205	1	**FUCA**	0.602	1
WSA	0.2794	2	**WSA**	0.4912	2

According to Table 10, FUCA scores have higher average Entropy scores and rho coefficients than WSA scores if the average of the periods is taken as a basis.

The above results contain very stable, satisfactory and consistent information for the comparison of MCDM methods. Both validation measures confirm that FUCA's performance is higher. Both criteria tell us the same thing. It is clear that FUCA is more successful than WSA. Another common point of the two methods is that WSA is more successful only in one base period than the other.

Discussion

Entropy, which is one of the objective weighting or estimation methods, determines the information content as a paradigm. In this respect, it is based on a believed or assumed acceptance. In general, the greater the difference between the values in the column, the more valuable the information contained in that column (criterion, indicator) for objective weight estimation methods. In other words, the weight of a criterion is higher in direct proportion to the information content (Mukhametzyanov, 2021). So the column should not necessarily be a criterion or indicator of any MCDM. In fact, the result scores or values of the MCDM methods are also included in a column. And they also have an amount of information content. Thus, the Entropy approach can formally be used to explore the informational content of the final scores produced by MCDM methods. This approach can be evaluated if the comparative results are consistent, stable and meaningful. This comparison has clearly been applied in this study, and the results are significantly consistent.

There is no rational or formal obstacle in calculating the Entropy of the MCDM final scores. The interpretation of comparisons actually depends on the originality and consistency of the results. In this study, after the final scores of the MCDM methods were normalized, their Entropies were calculated to make comparison. This different approach creates an objective alternative, especially for unexperienced decision makers who have difficulty in deciding on the most appropriate MCDM method. There is no any other study that has applied this approach in this way before in the literature.

In this study, the second MCDM selection criterion is related to real life as an objective criterion. Some recent studies (Baydaş and Elma, 2021; Baydaş and Eren, 2021; Baydaş et al., 2022) indicate that the financial performance field potentially has a natural and specific MCDM selection solution. The focus of this solution is on the significant relationships between at least two variables. There are significant correlations between the share and the financial performance rankings that are produced by MCDM methods for different periods. In the mentioned study, it was emphasized that some MCDM methods such as PROMETHEE and FUCA consistently provided higher correlations between share price and financial performance of companies. In this study, FUCA achieved a similar success. It can be said that FUCA clearly captures or models real-life situations better. The following two objective verification mechanisms were proposed to reveal the hidden capacities of MCDM methods. The results of this study are interesting and unique in the literature. The evaluations of this study are the following:

- The most important finding of the study is that there are strong evidences about how beneficial to use entropy in MCDM comparison as an objective method. In other words, the ranking scores of an MCDM method contains some patterns as a set. And these patterns can be unique and characteristic. These patterns can even express superiority. Thus, based on these patterns, an appropriate and efficient MCDM method can be selected.
- This study is different from the classical and followed the entropy procedure, because it focuses on MCDM outputs (sort results) instead of inputs (criteria). Since the criteria are mainly been used for weighting in the classical entropy procedure, different criteria may be more essential in different base periods. In other words, the degree of significance of the weights changes frequently. On the other hand, in this study, entropy was used to

compare the amount of information of MCDM methods, and the entropy results are quite stable and consistent. The Rho performances of MCDM methods, which expresses both entropy and relationship with real life, are also similar. In other words, FUCA has mainly showed a better performance compared to the WSA method in some periods in terms of both entropy and rho criteria.

- As in this study, it is possible to measure the amount of information of MCDM methods through Entropy. The results of the study clearly demonstrate that FUCA has higher capacity, and it is more significant. As a trend, the WSA method has consistently maintained its second-ranked position.
- Entropy and Rho validation mechanism both agreed that FUCA outperformed WSA.
- WSA and FUCA methods are alternatives from two different schools to rank performance for multiple criteria. The analysis results for six periods confirm that FUCA is more efficient than WSA. It is noteworthy that FUCA can work without normalization.
- The subjective choice of any MCDM method also influences the determination of the best alternative. And this can affect the quality of the decision to be taken. As in this study, an appropriate financial performance measurement can be a good decision support for financial information users (company partners, creditors, suppliers, investors) who are interested in companies.
- While determining the most appropriate MCDM method, the relationship with real life and the amount of information can be used as a dual verification mechanism, as in this study. Thus, according to these criteria, a MCDM method with more capacity can be selected. Table 11 below clearly shows that the best performing companies can differ according to MCDM methods. In addition, the companies with the best financial performance according to the FUCA and WSA methods are also available in the table. Therefore, the decision maker needs to consider different results according to the MCDM selection.

Table 11. Top Performer Companies According to Different MCDMs in Six Period (2015-2020)

Period	Best Company for FUCA	Best Company for WSA
2015	RODRG	DOGUB
2016	GEDZA	MAKTK
2017	MAKTK	VANGD
2018	FMIZP	FMIZP
2019	POLTK	POLTK
2020	VANGD	NIBAS

Conclusion

For more than 20 years, MCDM-based recommendations have been made for the measurement of an appropriate and accurate financial performance. It is a hard task to determine the most appropriate MCDM method to use in a multi-criteria measurement. There are more than a hundred MCDM methods, and they all claim to suggest the best alternative. The best alternative is often different depending on the MCDM method chosen under different conditions. This situation represents an uncertainty for the decision maker. It is difficult to recommend an appropriate MCDM selection procedure in this uncertain environment. Most of the time, MCDM method selection is affected by factors such as the capabilities, compatibility with the problem, popularity, and software support of the method.

In this study, two different objective verification mechanisms are proposed for the automatic selection of a MCDM method. The first is the idea that the MCDM method with higher relations to real life is more appropriate. The second type of validation is formally the idea that whichever MCDM result string contains the higher amount of information, the MCDM method is more appropriate and has better capacity. While the first idea has already been applies in few studies and got positive results, the second idea has not been applied until this study. Interestingly, the second idea displayed consistent results in this study.

In this study, MCDM calculations were made for six-year base periods over 31 SME companies in terms of five financial criteria. Spearman rho and Entropy as objective comparison criteria to compare FUCA and WSA methods. Rho and Entropy values confirm with each other. Accordingly, FUCA has higher values in five of the six base periods for both criteria. In other words, FUCA produced a higher correlation with real life (share price) than the WSA method, and at the same time, the amount of information (entropy) it contained was higher. This shows that MCDM methods have different characteristics, tendencies and special capacities. Moreover, this shows that some MCDM methods can be compared according to this determined capacity value, and then more appropriate method can be selected.

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