İnsan ve Toplum Bilimleri Araştırmaları Dergisi
Journal of the Human and Social Science Researches
[2147-1185]
13 th Years

2024, 13 (2), 610-629 | Research Article

Hybrid Approach for the Financial Assessment of Companies using Fuzzy Multi-Criteria Decision-Making and Self-Organizing Maps

Fatih YİĞİT[1]

Abstract

This paper presents a 3-stage innovative approach for company assessment, integrating financial ratios with the Fuzzy Analytic Hierarchy Process (FAHP) and using an unsupervised artificial intelligence method, Self-Organizing Maps (SOM), for classification. Addressing the challenges of decision-making in resource allocation, the study combines accurate data with robust tools essential in turbulent economic times. FAHP, known for handling complex, uncertain information, is applied to refine the traditional company assessment methods by integrating different experts' opinions and conversion to numerical values. This study presents an innovative framework by integrating financial ratios, commonly used in company evaluation methodologies, with FAHP, which is capable of processing complex and uncertain data. The integration of financial ratios into FAHP enhances the accuracy and clarity in decision-making processes for evaluating and ranking companies while also allowing for the management of the inherent uncertainties in economic data. Furthermore, SOM, an unsupervised artificial intelligence method for company classification, is used. Net Profit Margin is the financial ratio evaluated with the highest weight among financial ratios by 0.38. After the FAHP phase, financial ratios obtained from the income statements and balance sheets of companies are multiplied by the respective weights for valuation. In the final phase, a total of 6 companies listed in the Borsa Istanbul Insurance Index are divided into 3 classes. The two companies receiving the highest valuation, AGESA (Agesa Life and Pension) and ANHYT (Anadolu Life Pension Joint Stock Company), have been classified as Class A. To show the performance of the proposed model, companies registered in the Electricity Sector XELKT registered 31 companies. Classification also performed well in that set. The paper contributes to the field by providing a detailed literature review, methodology, case study results, and discussions on the practical implications of this integrated assessment method and possible areas for further research and applications.

Keywords: Financial Analysis, Multi-Criteria Decision Making, Fuzzy Analytic Hierarchy Process, Machine Learning, Self-Organizing Map

Yiğit, F. (2024). Hybrid Approach for the Financial Assessment of Companies using Fuzzy Multi-Criteria Decision-Making and Self-Organizing Maps. Journal of the Human and Social Science Researches, 13(2), 610-629. https://doi.org/10.15869/itobiad.1404060

Geliş Tarihi	12.12.2023
Kabul Tarihi	16.04.2024
Yayın Tarihi	30.06.2024

1 Asst. Prof., Altınbaş University, Faculty of Engineering and Architecture, Industrial Engineering Department, Istanbul, Türkiye, fatih.yigit@altinbas.edu.tr, ORCID:0000-0002-7919-544X

İnsan ve Toplum Bilimleri Araştırmaları Dergisi
Journal of the Human and Social Science Researches
[2147-1185]
13 th Years

2024, 13 (2), 610-629 | Araştırma Makalesi

Bulanık Çok Kriterli Karar Verme ve Kendi Kendini Düzenleyen Haritalar Kullanarak Şirketlerin Finansal Değerlendirmesine Yönelik Hibrit Yaklaşım

Fatih YİĞİT[1]

Öz

Bu makale, finansal oranları Bulanık Analitik Hiyerarşi Süreci (FAHP) ile entegre eden ve sınıflandırma için denetimsiz yapay zeka yöntemi olan Kendi Kendini Düzenleyen Haritaları (SOM) kullanan şirketlerin finansal performanslarının değerlendirilmesi için 3 aşamalı yenilikçi bir yaklaşım sunmaktadır. Kaynak tahsisinde karar vermenin zorluklarını ele alan çalışma, doğru verileri çalkantılı ekonomik dönemlerde gerekli olan sağlam araçlarla birleştirmektedir. Karmaşık ve belirsiz bilgileri işlemesiyle bilinen FAHP, farklı uzmanların görüşlerini entegre ederek ve sayısal değerlere dönüştürerek geleneksel şirket değerlendirme yöntemlerini geliştirmek için uygulanır. Bu çalışma, karmaşık ve belirsiz verileri işleyebilen FAHP ile bütünleştirerek yenilikçi bir çerçeve sunmaktadır. Finansal oranların FAHP'ye entegrasyonu, şirketlerin değerlendirilmesi ve sıralanmasında doğruluğu ve karar verme süreçlerindeki netliği artırırken, ekonomik verilerin doğasındaki belirsizliklerin yönetilmesine olanak tanır. Ek olarak, şirket sınıflandırması için denetimsiz yapay zeka yöntemi olan SOM kullanımı, metodolojimizin etkinliğini gerçek hayat verileri üzerinden ispatlamaktadır. Çalışmanın sonuçlarına göre, Net Kâr Marjı, finansal oranlar arasında 0.38 ile en yüksek ağırlığa sahip olarak değerlendirilen finansal orandır. FAHP aşamasından sonra, firmaların gelir tablosu ve bilançolarından elde edilen finansal oranlar söz konusu ağırlıklarla çarpılarak değerleme gerçekleştirilmektedir. Son aşamada ise Borsa Istanbul-Sigorta Endeksinde işlem gören toplam 6 şirket 3 sınıfa göre ayrılmıştır. En yüksek değerlemeyi alan 2 firma, AGESA(Agesa Hayat ve Emeklilik) ile ANHYT (Anadolu Hayat Emeklilik Anonim Şirketi), A sınıfı olarak değerlendirilmiştir. Önerilen makalenin performansının tespiti için Elektrik sektöründe XELKT kayıtlı 31 firma ile de uygulama yapılmıştır. Makale, ayrıntılı bir literatür taraması, metodoloji, vaka çalışması sonuçları ve bu entegre değerlendirme yönteminin pratik uygulamaları ve daha ileri araştırma ve uygulamalar için olası alanlar hakkında tartışmalar sağlayarak alana katkıda bulunmaktadır.

Anahtar Kelimeler: Finansal Değerlendirme, Çok Kriterli Karar Verme, Bulanık Analitik Hierarşi Prosesi, Makine Öğrenmesi, Kendi-Kendini Düzenleye Haritalar.

Yiğit, F. (2024). Bulanık Çok Kriterli Karar Verme ve Kendi Kendini Düzenleyen Haritalar Kullanarak Şirketlerin Finansal Değerlendirmesine Yönelik Hibrit Yaklaşım*. *İnsan ve Toplum Bilimleri Araştırmaları Dergisi,* 13(2), 610-629. https://doi.org/10.15869/itobiad.1404060

Date of Submission	12.12.2023
Date of Acceptance	16.04.2024
Date of Publication	30.06.2024

1 Asst. Prof., Altınbaş University, Faculty of Engineering and Architecture, Industrial Engineering Department, İstanbul, Türkiye, fatih.yigit@altinbas.edu.tr, ORCID:0000-0002-7919-544X

1. Introduction

The decision to invest is essential to accurately utilize the resources correctly. Allocating resources such as capital deserves a detailed and scientific investment approach. Such a decision requires at least two aspects. The first aspect is to have the right data for decision-making, and the other aspect is to use the right tool for decision-making. The study aims to integrate these two essential aspects in an integrated approach.

Financial ratios are widely used approaches for the economic assessment of companies. Financial ratios are useful indicators of a firm's performance and financial situation (Ertuğrul & Karakaşoğlu, 2009). Companies registered in the stock exchange regularly publish their income statements and balance sheets to the public. Financial ratios are used to assess the performance of companies as well as their probability of failure (Aldolou & Perçin, 2018; Beaver, 1966; Ozturk & Karabulut, 2020). They are vital for an accurate analysis of the company's health and possible future performance. Financial ratios become critical in turbulent times. Also, the existence of multiple financial ratios may complicate such decisions. In the presence of numerous financial ratios, combining them to generate a single value representing a company's performance is vital. A multi-criteria decision-making approach would be ideal for developing such a performance.

The FAHP is among the methods used for the analysis of multiple criteria. AHP and its extension FAHP are widely used for multi-attribute decision-making (Kahraman, 2024). This paper introduces a novel approach that combines the power of financial ratios with the versatility of the FAHP to address the limitations of traditional company assessment methodologies. FAHP is a robust mathematical tool well-suited to handle complex decision-making problems that involve vague, subjective, or uncertain information. By integrating financial ratios with FAHP, we aim to provide a more comprehensive and accurate framework for evaluating and ranking companies while explicitly addressing and managing the inherent fuzziness in economic data. The FAHP offers a solution to these challenges by introducing the concept of fuzziness into the assessment process. FAHP allows decision-makers to explicitly model and manage uncertainty and imprecision in the assessment process. By hierarchically structuring the decision criteria and employing linguistic variables, FAHP enables the incorporation of subjective judgments, expert opinions, and vague data into the assessment. This method enhances decision-making by providing a more realistic representation of the complex factors influencing company assessments.

A typical method for such classification is ABC Analysis. For such classification, an unsupervised machine learning technique is performed to cluster them and assign them to relevant classes. The SOM clustering method is used for such classification. This paper presents a comprehensive framework for company assessment that leverages the power of financial ratios and the adaptability of the FAHP. We illustrate the practical application of this methodology by conducting case studies on a diverse set of companies across different industries. By doing so, we aim to demonstrate the efficacy and reliability of our approach in enhancing the accuracy and robustness of company assessments, particularly in the presence of uncertainty and imprecision inherent in financial data. The rest of this paper is organized as follows: Section 2 provides a literature review on company assessment techniques, financial ratios, and the FAHP, emphasizing the advantages of employing FAHP and also sharing other studies in the literature either on the same subject or using similar methodologies. Section 3 details the methodology, including the hierarchical structure, linguistic variables, and data collection procedures, highlighting the role of FAHP in addressing fuzziness. Section 4 presents the case study and its result, showcasing how FAHP enhances the assessment process. Finally, in Section 5, we offer conclusions and recommendations for future research in the field of company assessment, emphasizing the continued application and development of FAHP in this context.

The main contributions of the study can be summarized as follows.

In terms of the methodology employed, to the best of our research, this study is the first study that uses a hybrid approach of FAHP and SOM for financial assessment.

The proposed study also converts experts' opinions for the assessment of financial ratios. These weights can be used as inputs for other studies when such opinions are needed.

2. Literature Review

In the following section, the literature review is performed regarding the topics associated with the study. The literature review is conducted on the methods and goals used in the study.

2.1. Performance Assessment using Financial Ratios

Many studies use financial ratios for performance assessment and predicting companies' financial status. The first application of such a model dates back to long ago (Beaver, 1966). Since then, multiple studies have been performed using financial ratios. Studies mainly focus on assessing companies using financial ratios or predicting a company's likelihood of status, such as failure or bankruptcy.

A recent study calculated a business's default probability by analyzing financial ratios. Similar studies have also been performed in other sectors. A recent analysis was conducted in the cruise business sector. The industry is challenged and affected dramatically by incidents such as COVID-19. The paper aims to identify managerial and financial efficiency, capital structure options, solvency conditions, and corporate value dynamics. The leading companies are investigated to analyze their financial, accounting, and stock market performance based on convenient financial market metrics (Syriopoulos et al., 2020). The research examined the correlation between short-listed financial ratios and subsequent incidents of default. Additionally, it constructed a probability of default (PD) model to estimate the likelihood that a borrower will enter delinquency within a one-year timeframe. The study's findings revealed noteworthy associations between the two variables (Burova et al., 2021).

Also, similar studies are performed using increased financial ratios and a greater pool of companies. This aspect would contribute to the success of the proposed models. 37 financial ratios are determined using the balance sheet data of 80 companies from 2015–2018. Based on the study's results, the financial ratios and associated models performed efficiently to predict bankruptcy and insolvency risks. The main contribution to the literature is the analysis of variables and their relationship to financial difficulties (Voda et al., 2021). Financial ratios are also used to predict the company's future based on changes. The ratios are used to predict stock returns and cyclical movements of companies (Yu et al., 2023). As seen from the studies in the literature review conducted, financial ratios are widely used for performance assessment. As a result, the financial ratios with the details given in the methodology section are used as a part of the proposed model.

2.2. Fuzzy Analytic Hierarchy Process

The AHP, developed by Thomas L. Saaty, is a widely recognized decision-making framework that helps simplify and analyze complex decisions. It's mainly known for its structured approach, which involves decomposing a decision problem into a hierarchy of more easily comprehensible sub-problems, each of which can be analyzed independently. The process starts with creating a decision hierarchy, ranging from the overall goal at the top, through intermediate levels of criteria and sub-criteria, down to the level of alternatives at the bottom (Saaty, 1980).

In AHP, decision-makers compare the elements at each hierarchical level pair-wise, quantifying their relative importance on a scale typically ranging from 1 to 9. These comparisons are then used to calculate priority scales, essentially numerical values representing each element's relative dominance in decision-making. A key feature of AHP is its consistency check, a mathematical way to ensure that the comparisons are not random and adhere to a logical pattern.

Building on the foundation of AHP, the FAHP incorporates fuzzy logic, enhancing the model's ability to handle the uncertainties and vagueness inherent in human judgments. In FAHP, the crisp numerical judgments of AHP are replaced with fuzzy numbers, often represented as triangular or trapezoidal fuzzy numbers. These fuzzy numbers better capture the imprecision of human assessments, allowing for a more nuanced approach to comparing decision elements. Aggregating these fuzzy comparisons in Fuzzy AHP is a critical step, leading to the derivation of fuzzy weights for each criterion and alternative. This process involves sophisticated computational techniques and translates the fuzzy logic assessments into actionable decision-making criteria. Fuzzy AHP has been particularly beneficial when decision data is not precise or is influenced by subjective human interpretations, making it a valuable tool in fields like environmental management, software development, and risk assessment.

However, integrating fuzzy logic in AHP also brings challenges, primarily the increased complexity in computations and the need for a deeper understanding of fuzzy logic principles. Despite these challenges, the Fuzzy AHP method stands out for its ability to accurately model real-world situations, accommodating the ambiguity and subjectivity that often accompany human decision-making processes. Among Multi-Criteria Decision Making (MCDM), FAHP is ranked the second most used methodology, following AHP (Kubler et al., 2016). As a result, multiple studies are performed using AHP and FAHP extensions (Abusaeed et al., 2023; Başaran et al., 2023; Çolakoğlu & Şahi̇n, 2022; Demircan & Yetilmezsoy, 2023; Singh & Garg, 2017). They are widely used in different areas such as determination ERP priorities, prioritization of cost factors in agile software development (Abusaeed et al., 2023; Çolakoğlu & Şahi̇n, 2022).

On the other hand, the flexibility of AHP allows it to be used in different areas rather than selection among alternatives. FAHP is performed to classify container terminals. As can be seen from this study, hybrid applications allow for the extension of the use of MCDM methods to cover different application areas rather than just the selection of alternatives. (Adenso-Díaz et al., 2020). Also, in a recent study, AHP is the most used MCDM approach (Basílio et al., 2022). These findings are the main reasons for selecting the FAHP method in this study. Multiple studies conduct systematic literature review (SLR) on AHP and FAHP (Ishizaka & Mu, 2023; Labib et al., 2022; Madzík & Falát, 2022; Tavana et al., 2021). As AHP is a widely used approach, multiple studies perform systematic literature reviews. The details of the study may contribute to the accurate analysis and background of the methods used for MCDM (Basílio et al., 2022; Khan et al., 2020; Kubler et al., 2016; Liu et al., 2020; Tavana et al., 2021).

2.3. SOM

Self-organizing maps (SOMs) are a type of artificial neural network that can produce a low-dimensional, discretized representation of the input space of the training samples, called a feature map. Such a map can be used for the clustering of inputs. Such clustering can be converted to classification when a cluster centre is assigned to a class.

SOM is widely used for clustering problems for a wide range of applications. The flexibility of the SOM allows it to be applied in different areas. A recent study performed SOM for Comorbidities of Chronic Diseases in Serbia. The study identified hypertension as the most prevalent disease in Sumadija and western Serbia. Such geographical separation allows the clustering of data (Rankovic et al., 2023). A similar study in different areas is performed in Brazil. The study focused on the classification and characterization of desalted crude oil (Duyck et al., 2023). SOM is also used to classify companies. A recent study performed the clustering of OECD companies using sustainable development indicators (Yigit, 2023).

2.4. Hybrid Approaches for Financial Assessment

As given before, AHP and FAHP are among the widely used decision-making approaches. Their main advantage is the flexibility to combine different criteria for different problems. This aspect allows the use of both methods in other areas. As a result, AHP and FAHP are among the most widely used approaches for MCDM (Kubler et al., 2016). Due to this nature, hybrid approaches are commonly performed using these two methods.

A recent study using AHP for the risk assessment of aquatic animal introduction is performed. The analysis performed a risk assessment model for the evaluation of invasive species. Based on the study, introducing aquatic animals using the AHP is an effective method, and the proposed model supports the introduction and healthy breeding of aquatic animals. As a result, the proposed study performed well for the risk assessment (Zhang et al., 2023). MCDM is also performed using a hybrid approach for financial risk management. The financial health of the companies is assessed using MCDM approaches—a method TOPSIS is used for such analysis. The results showed that Hungary is an ideal company for investors (Nagy & Valaskova, 2023).

Similarly, hybrid approaches are used for the assessment using MCDM methods. The Turkish banking sector is evaluated using TOPSIS and AHP methods for weight assessment. Financial ratios are used for parameters (Seçme et al., 2009). An integrated approach is used for the assessment of Iranian cement companies. The approach integrated FAHP and TOPSIS for weight calculation. Similarly, financial ratios are used as inputs for performance calculation (Moghimi & Anvari, 2014).

As mentioned in the studies, AHP is a widely used approach for MCDM. Also, financial ratios are widely used and accepted criteria for assessing companies either financially or their risk in terms of insolvency or bankruptcy. Based on the wide usage of FAHP and financial ratios, the study performed a hybrid approach for the financial ratio analysis and eventual classification.

3. Proposed Hybrid Approach Model for Financial Assessment

The following section shows the relevant stages of the proposed approach. The proposed method has multiple stages for converting inputs to outputs. Inputs are expert opinions and companies' financial ratios. The results of the proposed model are weights of financial ratios and the final classification of companies. The details of the proposed model are given in Fig. (1).

3.1. Financial Ratios for Performance Assessment

Financial ratios are important metrics that help decision-makers assess a company's performance. They are widely used by scholars, as given in the literature review. Table 1 represents the list of financial figures used in the proposed study. The financial ratios are divided into 5 main criteria. They are liquidity, financial leverage, activity, profitability, and growth ratios. The details of the main criteria are given in the following sub-sections. The details can be found in the study of Ertugrul and Karakasoglu (2009).

3.1.1. Liquidity Ratios

Liquidity represents resources such as cash or any similar asset easily converted to currency. Liquidity is vital for companies to survive as it is the primary resource for short-term liabilities. Liquidity is essential for companies (Ertuğrul & Karakaşoğlu, 2009). There are 3 ratios grouped under liquidity ratios. They are, namely, current ratio, liquidity ratio, and quick ratio.

3.1.2. Financial Leverage Ratios

The financial leverage ratio assesses an organization's capacity to fulfil immediate and future obligations. This ratio signifies the degree of risk the company is exposed to in fulfilling debt service obligations (interest and principal repayment) (McGuigan et al., 2006). The financial leverage ratio analyzes the ability of the company to meet long-term liabilities. Four ratios fall under the category of financial leverage ratios. The ratios in question are the ratios of shareholders' equity to total assets, fixed assets to shareholders' equity, debt, and long-term debt to shareholders' equity (Ertuğrul & Karakaşoğlu, 2009).

3.1.3. Activity Ratios

Four ratios fall under the category of financial leverage ratios. The ratios in question are the ratios of shareholders' equity to total assets, fixed assets to shareholders' equity, debt, and long-term debt to shareholders' equity (McGuigan et al., 2006). Efficient use of resources is essential as it addresses the ability to generate resources. Furthermore, resources that are utilized efficiently are less susceptible to risks. As a result of an increase in receivables turnover, payment terms are shortened. In general, shorter payment terms mean a reduced likelihood of bad debt for the business. There are four ratios classified under the financial leverage ratios. They are inventory turnover, total asset turnover ratio, account receivable turnover, accounts receivable turnover, and accounts payable turnover ratio. Activity ratios increase in importance with high financial interest rates. Activity ratios are also called asset turnover ratios (Ertuğrul & Karakaşoğlu, 2009).

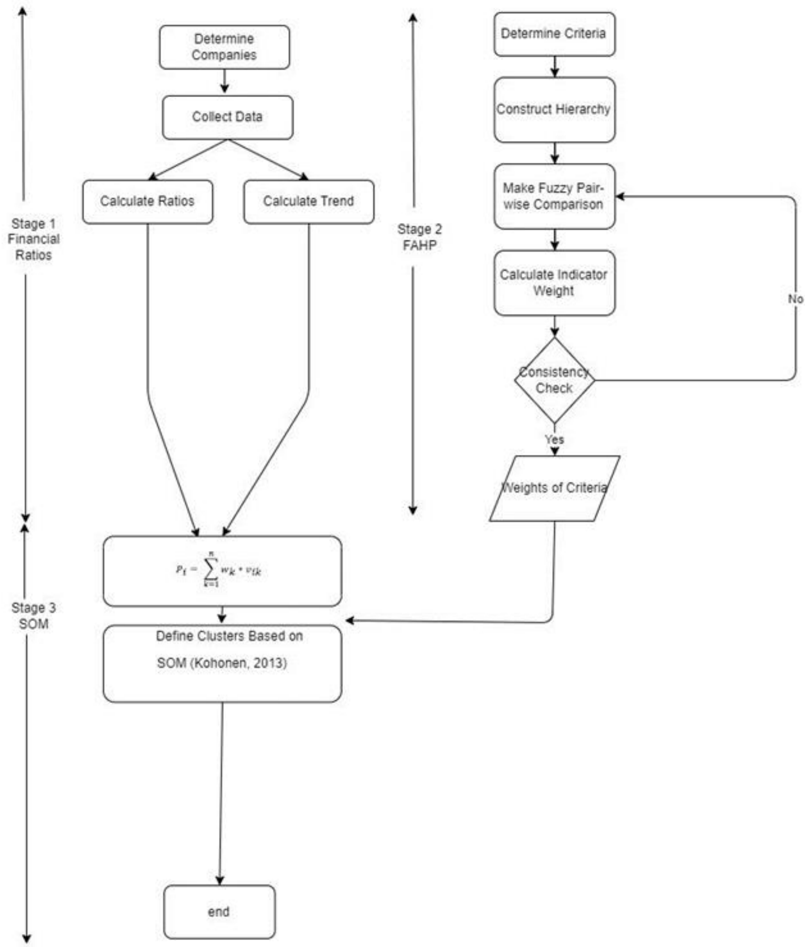

Figure 1 Workflow of the Proposed Model

3.1.4. Profitability Ratios

Profit is the primary goal of a company. Sustainable profit generation is vital for a company as it allows it to grow, invest, and allocate resources for long-term requirements such as research and development. There are many aspects of profit as costs cover different aspects of the business. The main cost drivers are direct costs, indirect costs, and financial costs. Two types of profitability ratios are used for the assessment. They are the net profit margin ratio and return on equity ratio (Ertuğrul & Karakaşoğlu, 2009).

3.1.5. Growth Ratios

Growth is essential for a company as it is a vital performance metric to show its position versus competitors. Growth is necessary as it allows companies to indicate the general market position and its predictions. Growth also enables the company to lower fixed costs and positively affects the profitability ratios in the short term. There are two main types of growth ratios. They are the profit margin ratio and return on equity ratio. The details of the financial ratios are given in the study proposed by Ertugrul and Karakasoglu (2009).

Table 1 Financial Ratios

Main Criteria No	Main Criteria Description	Criteria no	Criteria description
S1	Liquidity Ratios	S6	Current Ratio
		S7	Quick Ratio
		S8	Cash Ratio
S2	Financial Leverage Ratios	S9	Debt Ratio
		S10	Shareholder's Equity/Assets
		S11	Fixed Assets/Shareholder's Equity
		S12	Fixed Assets/Long-Term Debt
S3	Activity Ratios	S13	Account Receivable Ratio
		S14	Inventory Turnover Ratio
		S15	Current Assets Turnover Ratio
		S16	Total Asset Turnover Ratio
		S17	Accounts Payable Turnover Ratio
S4	Profitability Ratios	S18	Net Profit Margin
		S19	Return on Equity
S5	Growth Ratios	S20	Sales Growth
		S21	Operating Profit Growth
		S22	Shareholders' Equity Growth
		S23	Assets Growth

3.2. FAHP

FAHP is a method to convert expert opinions to weights by using bi-comparison among criteria. The inputs of the FAHP are expert opinions using cross-comparisons. After applying the following workflow, the outputs are generated as weights.

Step 1 Setup Hierarchy Architecture

Step 2 Setup Fuzzy Pair-wise Comparison Matrix Using Opinions from each Decision Maker

$$\bar{D} = \begin{bmatrix} (1,1,1) & a_{12} & \cdots & a_{1n} \\ a_{21} & (1,1,1) & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & \cdots & \cdots & (1,1,1) \end{bmatrix}$$

where aij x aji = 1 and aij = wi / wj   i, j = 1, 2, 3, 4,…n

Step 3 The fuzzy geometric value is calculated to combine multiple opinions as given in Eq.(1)

$$\check{r}_i = (a_{i1}\ x\ a_{i2}\ x \ldots\ x\ a_{in})^{1/n} \quad (1)$$

Step 4 The fuzzy weight $\breve{w}_i$ for each criterion, i is calculated as given in Eq. 2

$$\breve{w}_i = (\check{r}_i\ x\ (\check{r}_1 + \check{r}_2 + \cdots + \check{r}_n)^{-1}) \quad (2)$$

where $\check{r}_k = (l_k, m_k, u_k)$

Step 5 The fuzzy weights are defuzzied by using any available methods. CoA is used for this case. The Eq. is given in Eq. 3. ((Buckley, 1985 ;Tzeng & Huang, 2011)

$$\breve{w}_i = (\frac{l_i + m_i + u_i}{3}) \quad (3)$$

3.3. Self Organizing Maps

Kohonen Systems, often known as SOM, is an unsupervised learning technique that can solve various dimensionality reduction or categorization issues. A map, a low-dimensional, discretized representation of the training samples' input space, is created as an output of SOM. After the training phase, often in a two- or three-dimensional perspective, the high-dimensional input data is generated while maintaining the topological features of the data (Kohonen, 2013). Fig. (2) represents the graphical representation of the SOM Model.

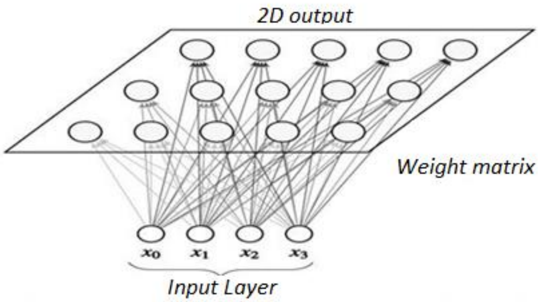

Figure 2 General Diagram for SOM(Kohonen, 2013)

Input and output neurons of the SOM architecture are seen in Fig. 1, and weights from each input neuron are replicated to each output neuron. Each input neuron is chosen in SOM, and the distances between it and each output neuron are computed. The best matching neuron (BMU) or winning neuron is the nearest neuron. The weights between the winner neuron and the chosen input neuron are then updated. The SOM grid updates the BMU and nearby neurons' weights relative to the input vector. The size of the change gets smaller with the grid distance from the BMU as time increases. All inputs are subjected to this procedure until a predefined number of cycles or a threshold value is reached. The network consequently links the output nodes to the input dataset. The following steps can be used to summarise the SOM algorithm:

Step 1-Initialise the weights and parameters.

Step 1-Choose a random input sample,

Step 2-Choose the best matching BMU,

Step 3-Update the weight vectors of the nodes near the BMU,

Step 4- Repeat the process until the maximum number of iterations has been reached.

4. Application of the Proposed Method

In the following subsections, the details of the proposed model's application are provided.

4.1. Stage-1 Financial Ratios

The company's financial ratios are used to apply the proposed method. A group of companies registered in the Istanbul Stock Exchange are selected to apply the case. The insurance sector (XSGRT) and electric sector (XELKT) are used for the assessment. There are 6 and 31 companies registered in XSGRT and XELKT, respectively. Although the number of companies is limited, they are chosen as they represent established companies. The names of the companies are given in Table 2 and Table 8.

As given in Section 3.1, there are 18 ratios as a part of financial ratios. 10 of the financial ratios are selected for the assessment of companies. The ratios mainly used for manufacturing companies, such as inventory turnover ratios, have been removed from the list. The ratios selected for the assessment also make 84% weight among all financial ratios of a recent study. A recent study assessed that the main criteria are Current Ratio, Cash Ratio, Debt Ratio, Net Profit Margin, and Return on Equity based on expert opinions (Yiğit, 2023). The same financial ratios are used as inputs for FAHP to reduce the complexity. The financial ratios are calculated based on the annual financial tables and income statements, and the latest annual financial tables 2023/12 are used for the model for XSGRT. 2013/09 is used for XELKT, as that is the period available for all companies. The ratios are normalized to convert them to the same scale. Finally, the following financial ratios are calculated as the outputs of the first stage. The rate of each company is given in Table 3. FRxy represents the financial ratios of the financial ratio x for the company y.

4.2. Stage-2 FAHP

In the second stage, FAHP is performed for analysis. Three expert opinions are received, and the arithmetic mean for group assessment is performed. The experts are chosen based on their expertise in using financial ratios. The first expert is a financial controller with 20 years of experience. The second expert is the chief financial officer. Using financial ratios to assess a company is a part of the job description. The third expert is a sworn-in certified accountant. The expert has expertise in evaluating financial tables and making predictions and evaluations accordingly. Based on the analysis, three inputs are received, and evaluation is performed to convert the inputs to weights. A Likert scale is used for the assessment, as shown in Table 4.

Based on these inputs, the FAHP process is applied. In this stage, the weight of each financial ratio is calculated. Based on these weights, the performance of each company is calculated. The 10 ratios that have the highest weights are taken into consideration. The outputs of each financial ratio are given in Table 5. As presented, the weights represent the importance of ratios. As shown in Table 5, the net profit margin is the primary ratio. This result is expected and contributes to our model's robustness. The profit is the primary driver of a company. The outputs of Stage 2 are given in Table 5. W_x represents the weight of each financial ratio calculated as the arithmetic mean of 3 experts' assessments.

Table 2 Company Names

BIST Code	*Company Name*
AGESA	Agesa Hayat ve Emeklilik
AKGRT	Aksigorta
ANHYT	Anadolu Hayat Emeklilik Anonim Şirketi
ANSGR	Anadolu Sigorta
RAYSG	Ray Sigorta
TURSG	Türkiye Sigorta

Table 3 Financial Ratios of XSGRT (FRxy)

Criteria	*AGESA*	*AKGRT*	*ANHYT*	*ANSGR*	*RAYSG*	*TURSG*
Current Ratio	1.00	0.02	0.00	0.04	0.03	0.02
Quick Ratio	1.00	0.09	0.00	0.13	0.09	0.14
Cash Ratio	1.00	0.09	0.00	0.13	0.09	0.14
Debt Ratio	1.00	0.39	0.91	0.00	0.26	0.19
Shareholder's Equity/Assets	0.00	0.61	0.09	1.00	0.74	0.81
Net Profit Margin	0.00	0.48	0.09	1.00	0.82	0.87
Return on Equity	0.83	0.00	0.72	0.78	1.00	0.66
Sales Growth	0.22	0.00	0.14	0.23	0.32	1.00
Operating Profit Growth	0.75	0.55	0.31	0.00	0.32	1.00
Shareholders' Equity Growth	0.09	0.00	0.24	0.92	0.81	1.00

Table 4 Fuzzy Triangular Scale, Definitions and Saaty Scale(Buckley, 1985)

Saaty Scale	*Definition*	*Fuzzy Triangular Scale*	*Reciprocal Fuzzy Triangular Scale*
1	Equally Important	[1, 1, 1]	[1, 1, 1]
3	Weakly Important	[2, 3, 4]	[1/4, 1/3, 1/2]
5	Fairly Important	[4, 5, 6]	[1/6, 1/5, 1/4]
7	Strongly Important	[6, 7, 8]	[1/8, 1/7, 1/6]
9	Important	[9, 9, 9]	[1/9, 1/9, 1/9]

Table 5 Weights of Criteria

Criteria	Weight
Current Ratio	*0.19*
Quick Ratio	*0.05*
Cash Ratio	*0.14*
Debt Ratio	*0.08*
Shareholder's Equity/Assets	*0.05*
Net Profit Margin	*0.38*
Return on Equity	*0.06*
Sales Growth	*0.01*
Operating Profit Growth	*0.02*
Shareholders' Equity Growth	*0.01*

4.3. Stage-3 SOM Application for XSGRT Companies

The weights of financial ratios are the inputs of Stage 3. The equation is given as in Eq. (4). In Eq. (4), x represents the financial ratios, and y represents the company index. TS_y represents the total score according to weights and company assessments. Fig. (3) and Fig. (4) describe the graphical representation of the application of SOM for 6 candidates for 3 clusters. Table 6 represents the total score of each company.

$$\sum_{x} W_x * FR_{xy} = TS_y \quad (4)$$

Table 6 Total Score

Company	AGESA	AKGRT	ANHYT	ANSGR	RAYSG	TURSG
TS_y	0.59	0.22	0.25	0.42	0.45	0.58

Based on these results, SOM is performed for clustering. Based on the SOM classification, the 6 companies are classified into 3 classes: A, B, and C. As shown in Table 7, AGESA is the best-performing companies. AKGRT represents the lowest-performing company in the XSGRT index.

4.4. Stage-3 SOM Application for XELKT Companies

The number of XSGRT sectors is limited. As a result, the proposed model is also conducted in a sector with a number of companies. Energy is a major sector that has 31 companies registered in Borsa Istanbul. The same SOM application is performed for the XELKT sector. The classification results after the SOM stage are given in Fig. (5) and Fig. (6). Fig. (5) represents the split of data with weight positions, and Fig. (6) represents each cluster member number.

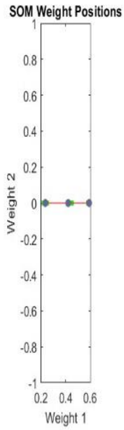

Figure 3
SOM Weights Positions - XSGRT

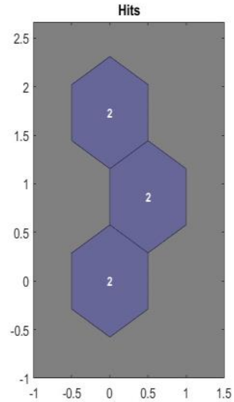

Figure 4
ABC Classification Results - XSGRT

Table 7 Classification of XSGRT Companies

Company	***AGESA***	***AKGRT***	***ANHYT***	***ANSGR***	***RAYSG***	***TURSG***
Total Score	0.59	0.22	0.25	0.42	0.45	0.58
Class	A	C	C	B	B	A

The performance values based on Stage and 2 are given after the classification in Table 8. As given in Table 8, there are only 3 companies under A class. This result shows the importance of having a greater dataset for the model

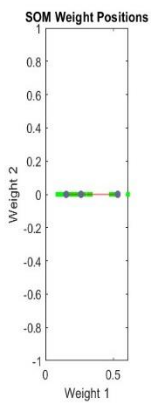

Figure 5
SOM Weights Positions - XELKT

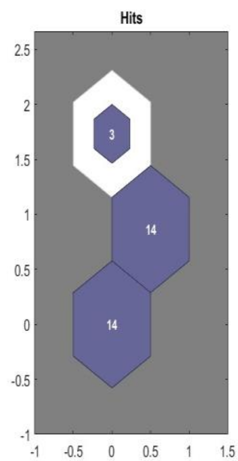

Figure 6
ABC Classification Results - XELKT

Table 8 XELKT Classification of Companies based on ABC Analysis

Company	*Name*	*TS_y*	*Class*
GWIND	Güriş Wind Energy Inc.	0.61	A
MAGEN	Marmara Enerji A.Ş.	0.51	A
TATEN	Tarsus Termik Santrali Elektrik Üretim A.Ş.	0.48	A
ODAS	Odas Elektrik Üretim A.Ş.	0.33	B
ESEN	Eskişehir Enerji Santrali Elektrik Üretim A.Ş.	0.32	B
IZENR	İzmit Enerji Santrali Elektrik Üretim A.Ş.	0.29	B
ALFAS	Alfa Solar Enerji Sanayi Ve Ticaret A.Ş.	0.28	B
AYDEM	AYDEM Enerji	0.27	B
NATEN	Narlıdere Termik Santrali Elektrik Üretim A.Ş.	0.27	B
ARASE	Aras Elektrik Dağıtım A.Ş.	0.26	B
BIOEN	Biogaz Enerji Üretim A.Ş.	0.26	B
AHGAZ	Ahmetbey Gaz Dağıtım A.Ş.	0.24	B
ENJSA	Enerjisa Enerji Satış A.Ş.	0.24	B
CANTE	Çanakkale Termik Santrali Elektrik Üretim A.Ş.	0.24	B
NTGAZ	Natura Gaz Dağıtım A.Ş.	0.23	B
ZEDUR	Zeytinburnu Enerji A.Ş.	0.22	B
SMRTG	Smart Energy A.Ş.	0.22	B
AKENR	Akenerji Elektrik Üretim A.Ş.	0.19	C
CWENE	Çatalağzı Wind Energy Inc.	0.19	C
AKSUE	Akçansa Üstyapı ve Enerji Yatırımları A.Ş.	0.19	C
AYEN	Ayen Enerji A.Ş.	0.19	C
AKFYE	Akfen Yenilenebilir Enerji A.Ş.	0.19	C
AKSEN	Akçansa Çimento Sanayi ve Ticaret A.Ş.	0.17	C
ENERY	Enerjisa Enerji Üretim A.Ş.	0.15	C
MOGAN	Mogan Enerji A.Ş.	0.14	C
BASGZ	Başkent Gaz Dağıtım A.Ş.	0.14	C
KARYE	Karadeniz Enerji A.Ş.	0.14	C
CATES	Çatalağzı Termik Santrali Elektrik Üretim A.Ş.	0.14	C
ZOREN	Zorlu Enerji Elektrik Üretim A.Ş.	0.12	C
HUNER	Hünkar Enerji A.Ş.	0.10	C
CONSE	Çorlu Doğalgaz Santrali Elektrik Üretim A.Ş.	0.09	C

5. Conclusion

Financial ratios are essential inputs for the assessment of a company's performance. MCDM is a group of methods used to analyze and assess alternatives and eventual choices. This study aims to apply a known MCDM for analysis and assessment, among other options. The proposed research employs a 3 stage application for converting financial ratios and expert opinions for the classification of companies. The outputs of the first stage are financial ratios. The most essential 10 financial ratios defined in another study are chosen. Based on expert opinions, Net Profit Margin, Cash Ratio and Current Ratio are the criteria with the highest weights. In the second stage, FAHP is applied to define weights based on experts' opinions. Three experts are used for the assessment. For the third stage, inputs from the first and second stages, namely financial ratios and weights, are used.

The performance of each company is calculated based on the weights and financial ratios. The results showed that AGESA performs best and AKGRT has the lowest performance. Their performance is 0.59 and 0.22 on a scale between 0 and 1. In the last stage, the SOM method is performed for clustering, and based on this clustering, 2 companies are classified under the A class, AGESA and TURSG, while AKGRT and ANHYT are within the lowest class of C. The study is new in the literature as it integrates FAHP and SOM methods for financial assessment. The use of unsupervised clustering techniques for classification is important for classifying inputs. The study is conducted in the insurance sector XSGRT registered in Borsa Istanbul. To the best of our research, such an application is new in the literature. Due to the limitations given below, the same model is applied in a different sector. The XELKT sector that covers companies in electricity is used for the assessment. 3 companies are classified as A group under 31 companies registered in the sector. The companies registered are GWIND, MAGEN and TATEN.

The study has limitations. The model has a limited dataset. The 6 companies for XSGRT and 31 companies for XELKT may not be adequately assessed, but the database will be extended for further research. Also, 3 experts may not be enough to cover a wide range of opinions. 3 experts are chosen with enough experience, but additional experts may contribute to the enrichment of the potential of the proposed method. The selection of 10 ratios may not adequately assess the importance of companies. Future research will focus on improving the limitations. The expert pool will be extended to cover a broader range of inputs. Manual calculation of financial ratios limits the applicability of the proposed model. Software using automated data retrieval and financial ratio calculation may be beneficial for extending the proposed model to a broader range.

Based on our assessment, the study performed an analysis as expected. The study achieved its goal of classifying insurance companies using financial ratios. The study was also performed to assess the importance of financial ratios. Net profit margin is found to be the most important financial ratio. This finding is also confirmed by the findings of the study (Vibhakar et al., 2023). The main area for researchers is to extend the study with an extended pool of experts to have a more homogenous assessment. Also, applications in different sectors may help to apply to different datasets. A comparison with different assessments, such as those of experts, may help analyze the discrepancies.

Peer-Review	Double anonymized - Two External
Ethical Statement	*It is declared that scientific and ethical principles have been followed while carrying out and writing this study and that all the sources used have been properly cited.* * (Altinbas University Rectorate, Scientific Research and Ethics Committee Decision was taken with the decision dated 06.05.2024, numbered 2024/5 of the Presidency of the Publication Ethics Committee.)
Plagiarism Checks	Yes - Turnitin
Conflicts of Interest	The author(s) has no conflict of interest to declare.
Complaints	itobiad@itobiad.com
Grant Support	The author(s) acknowledge that they received no external funding in support of this research.
Değerlendirme	İki Dış Hakem / Çift Taraflı Körleme
Etik Beyan	*Bu çalışmanın hazırlanma sürecinde bilimsel ve etik ilkelere uyulduğu ve yararlanılan tüm çalışmaların kaynakçada belirtildiği beyan olunur.* *(Altinbaş Üniversitesi Rektörlüğü, Bilimsel Araştırma ve Yayın Etiği Kurulu Başkanlığının 06.05.2024 Tarih , 2024/5 Nolu kararı ile Etik Kurul Kararı alınmıştır.)
Benzerlik Taraması	Yapıldı – Turnitin
Etik Bildirim	itobiad@itobiad.com
Çıkar Çatışması	Çıkar çatışması beyan edilmemiştir.
Finansman	Bu araştırmayı desteklemek için dış fon kullanılmamıştır.

References / Kaynakça

Abusaeed, S., Khan, S. U. R., & Mashkoor, A. (2023). A Fuzzy AHP-based approach for prioritization of cost overhead factors in agile software development. Applied Soft Computing, 133, 109977. https://doi.org/10.1016/j.asoc.2022.109977

Adenso-Díaz, B., Álvarez, N. G., & Alba, J. A. L. (2020). A fuzzy AHP classification of container terminals. Maritime Economics and Logistics, 22(2), 218–238. https://doi.org/10.1057/s41278-019-00144-4

Aldalou, E., & Perçin, S. (2018). Financial Performance Evaluation of Turkish Airline Companies Using Integrated Fuzzy Ahp Fuzzy Topsis Model*. Uluslararası İktisadi ve İdari İncelemeler Dergisi. https://doi.org/10.18092/ulikidince.347925

Basílio, M. P., Pereira, V., Costa, H. G., Santos, M., & Ghosh, A. (2022). A Systematic Review of the Applications of Multi-Criteria Decision Aid Methods (1977–2022). In Electronics (Switzerland) (Vol. 11, Issue 11). MDPI. https://doi.org/10.3390/electronics11111720

Başaran, Y., Aladağ, H., & Işık, Z. (2023). Pythagorean Fuzzy AHP Based Dynamic Subcontractor Management Framework. Buildings, 13(5), 1351. https://doi.org/10.3390/buildings13051351

Beaver, W. (1966). Financial Ratios As Predictors Of Failure. https://doi.org/10.2307/2490171

Buckley, J. J. (1985). Fuzzy hierarchical analysis. Fuzzy Sets and Systems, 17(3), 233–247.

Burova, A., Penikas, H., & Popova, S. (2021). Probability of Default Model to Estimate Ex Ante Credit Risk. Russian Journal of Money and Finance. https://doi.org/10.31477/RJMF.202103.49

Çolakoğlu, N., & Şahïn, Z. (2022). Determining of Priorities in ERP Project Management with AHP Approach. Eurasian Academy of SciencesEurasian Business & Economics Journal 30, 39-63

Demircan, B. G., & Yetilmezsoy, K. (2023). A Hybrid Fuzzy AHP-TOPSIS Approach for Implementation of Smart Sustainable Waste Management Strategies. Sustainability, 15(8), 6526. https://doi.org/10.3390/su15086526

Duyck, C., da Silva Viana Jacobson, L., Rodrigues de Souza, J., Chavez Rocha, R. C., Oliveira, C. J. F., Oliveira da Fonseca, T. C., & Saint'Pierre, T. D. (2023). Brazilian basins characterization based on the distributions of elements in desalted crude oils using classical multivariate analysis and kohonen self-organizing map. Geoenergy Science and Engineering, 223. https://doi.org/10.1016/j.geoen.2023.211502

Ertuğrul, I., & Karakaşoğlu, N. (2009). Performance evaluation of Turkish cement firms with fuzzy analytic hierarchy process and TOPSIS methods. Expert Systems with Applications, 36(1), 702–715. https://doi.org/10.1016/j.eswa.2007.10.014

Ishizaka, A., & Mu, E. (2023). What is so special about the analytic hierarchy and network process? In Annals of Operations Research (Vol. 326, Issue 2, pp. 625–634). Springer. https://doi.org/10.1007/s10479-023-05412-4

Kahraman, C. (2024). Proportional picture fuzzy sets and their AHP extension: Application to waste disposal site selection. Expert Systems with Applications, 238, 122354. https://doi.org/10.1016/j.eswa.2023.122354

Khan, A. U., Khan, A. U., & Ali, Y. (2020). ANALYTICAL HIERARCHY PROCESS (AHP) AND ANALYTIC NETWORK PROCESS METHODS AND THEIR APPLICATIONS: A TWENTY YEAR REVIEW FROM 2000–2019. International Journal of the Analytic Hierarchy Process, 12(3), 369–402. https://doi.org/10.13033/IJAHP.V12I3.822

Kohonen, T. (2013). Essentials of the self-organizing map. Neural Networks, 37, 52–65. https://doi.org/https://doi.org/10.1016/j.neunet.2012.09.018

Kubler, S., Robert, J., Derigent, W., Voisin, A., & Le Traon, Y. (2016). A state-of the-art survey & testbed of fuzzy AHP (FAHP) applications. Expert Systems with Applications, 65, 398–422. https://doi.org/10.1016/j.eswa.2016.08.064

Labib, A., Abdi, M. R., Hadleigh-Dunn, S., & Yazdani, M. (2022). Evidence-Based Models To Support Humanitarian Operatıons And Crisis Management. Decision Making: Applications in Management and Engineering, 5(1), 113–134. https://doi.org/10.31181/dmame030222100y

Liu, Y., Eckert, C. M., & Earl, C. (2020). A review of fuzzy AHP methods for decision-making with subjective judgements. Expert Systems with Applications, 161, 113738. https://doi.org/10.1016/j.eswa.2020.113738

Madzík, P., & Falát, L. (2022). State-of-the-art on analytic hierarchy process in the last 40 years: Literature review based on Latent Dirichlet Allocation topic modelling. In PLoS ONE (Vol. 17, Issue 5 May). Public Library of Science. https://doi.org/10.1371/journal.pone.0268777

McGuigan, J. R., Kretlow, W. J., Moyer, R. C., & Wang, B. (2006). Contemporary financial management. Thomson/South-Western.

Moghimi, R., & Anvari, A. (2014). An integrated fuzzy MCDM approach and analysis to evaluate the financial performance of Iranian cement companies. The International Journal of Advanced Manufacturing Technology, 71(1–4), 685–698. https://doi.org/10.1007/s00170-013-5370-6

Nagy, M., & Valaskova, K. (2023). An Analysis of the Financial Health of Companies Concerning the Business Environment of the V4 Countries. Folia Oeconomica Stetinensia. https://doi.org/10.2478/FOLI-2023-0009

Ozturk, H., & Karabulut, T. A. (2020). Impact of financial ratios on technology and telecommunication stock returns: Evidence from an emerging market. Investment Management and Financial Innovations, 17(2), 76–87. https://doi.org/10.21511/imfi.17(2).2020.07

Rankovic, N., Rankovic, D., Lukic, I., Savic, N., & Jovanovic, V. (2023). Unveiling the Comorbidities of Chronic Diseases in Serbia Using ML Algorithms and Kohonen Self-Organizing Maps for Personalized Healthcare Frameworks. Journal of Personalized Medicine, 13(7). https://doi.org/10.3390/jpm13071032

Saaty, T. (1980). The analytic hierarchy process (AHP) for decision making. Kobe, Japan, 1–69.

Seçme, N. Y., Bayrakdaroğlu, A., & Kahraman, C. (2009). Fuzzy performance evaluation in Turkish Banking Sector using Analytic Hierarchy Process and TOPSIS. Expert Systems with Applications, 36(9), 11699–11709. https://doi.org/10.1016/j.eswa.2009.03.013

Singh, S., & Garg, H. (2017). Distance measures between type-2 intuitionistic fuzzy sets and their application to multi-criteria decision-making process. Applied Intelligence. https://doi.org/10.1007/S10489-016-0869-9

Syriopoulos, T., Tsatsaronis, M., & Gorila, M. (2020). The global cruise industry: Financial performance evaluation. Research in Transportation Business and Management, September, 100558. https://doi.org/10.1016/j.rtbm.2020.100558

Tavana, M., Soltanifar, M., & Santos-Arteaga, F. J. (2021). Analytical hierarchy process: revolution and evolution. Annals of Operations Research. https://doi.org/10.1007/s10479-021-04432-2

Tzeng, G.-H., & Huang, J.-J. (2011). Multiple attribute decision making: methods and applications. CRC press.

Vibhakar, N. N., Tripathi, K. K., Johari, S., & Jha, K. N. (2023). Identification of significant financial performance indicators for the Indian construction companies. International Journal of Construction Management, 23(1), 13–23. https://doi.org/10.1080/15623599.2020.1844856

Voda, A. D., Dobrotă, G., Țîrcă, D. M., Dumitrașcu, D. D., & Dobrotă, D. (2021). Corporate bankruptcy and insolvency prediction model. Technological and Economic Development of Economy, 27(5), 1039–1056. https://doi.org/10.3846/tede.2021.15106

Yiğit, F. (2023). Classification of XTEKS Companies During COVID-19 Pandemic using Fuzzy-Analytic Hierarchy Process and Fuzzy-C-Means. In I. U. and O. B. and C. S. and C. O. S. and T. A. Ç. Kahraman Cengiz and Sari (Ed.), Intelligent and Fuzzy Systems (pp. 609–616). Springer Nature Switzerland.

Yigit, P. (2023). Self-Organizing Maps Approach for Clustering OECD Countries Using Sustainable Development Indicators. İnsan ve Toplum Bilimleri Araştırmaları Dergisi, 12(5), 2850–2869. https://doi.org/10.15869/itobiad.1370419

Yu, D., Huang, D., & Chen, L. (2023). Stock return predictability and cyclical movements in valuation ratios. Journal of Empirical Finance, 72, 36–53. https://doi.org/10.1016/j.jempfin.2023.02.004

Zhang, X., Du, H., Zhao, Z., Wu, Y., Cao, Z., Zhou, Y., & Sun, Y. (2023). Risk Assessment Model System for Aquatic Animal Introduction Based on Analytic Hierarchy Process (AHP). Animals, 13(12). https://doi.org/10.3390/ani13122035