Journal of Turkish

Operations Management

# A new integrated criteria weighting approach for determining production priority in demand management

**Elif Kılıç Delice[1]*, Elif Akviran[2]**

[1]Industrial Engineering Department, Faculty of Engineering, Atatürk University, Erzurum, Turkey
e-mail: elif.kdelice@atauni.edu.tr, ORCID No: http://orcid.org/0000-0002-3051-0496
[2]A101 Yeni Mağazacılık A.Ş., İzmir, Turkey
e-mail: akviranelif@gmail.com, ORCID No: http://orcid.org/0000-0003-2776-2374
*Corresponding Author

**Article Info**

**Article History:**
Received: 27.12.2023
Revised: 25.09.2024
Accepted: 12.10.2024

**Keywords:**

Production Priority,
LBWA,
CRITIC,
SOWIA

**Abstract**

The demand management process aims to strike a balance between the customers' needs and the company's supply possibilities. Effective demand management starts with effective stock control and tracking of customer orders and ends with customer satisfaction. Determining production priorities correctly is one way to increase customer satisfaction. In this context, a new integrated approach based on Multi Criteria Decision Making (MCDM) is proposed to determine the production priority needed in the demand management process. The first step of this three-step process determines customer alternatives. Production priority criteria are established in the second stage based on the attributes of the customer. In the third step, objective and subjective criterion weights are determined by taking into account real data and expert opinions using the LBWA (Level Based Weight Assessment) and CRITIC (The Criteria Importance Through Intercriteria Correlation) methods. Then, the integrated criteria weights are determined by the SOWIA (Subjective and Objective Weight Integrated Approach) using objective and subjective criteria weights. In the literature, there are few studies that determine production priority using the MCDM method. In addition, no study was found in the literature in which quantitative and qualitative methods were integrated in the ceramic industry. It is believed that this study will contribute to the literature.

## 1. Introduction

In today's world, there are many businesses that have decided to downsize due to economic difficulties. Contrary to the businesses' decision to downsize, the increasing population and the resulting increased demand have caused a slowdown in customer returns. In order for a business to avoid downsizing and to survive in the face of economic difficulties, it is necessary to use its limited production resources in a way that will maximize efficiency and increase its profitability, considering the interests of the business.

Managers must increase customer satisfaction and manage demand effectively, considering limited production resources and business profitability. However, determining production priorities in demand management is extremely important. It has been noted that most organizations focus their decision-making on the decision maker's experience rather than employing an excessive number of mathematical methods in real-world scenarios. However, decisions may not always be the right ones, depending on the information and comprehension of those making them. In making these selections, actual customer data should also be taken into account. Thus, a novel solution approach based on Multi-Criteria Decision Making (MCDM) is suggested within the parameters of the study, enabling firms to quickly establish production priorities by utilizing real customer data as well as decision makers' experiences (Bayram, 2022).

MCDM can be defined as the decision maker's selection process using at least two criteria from a set consisting of a finite countable or an infinite number of uncountable options, or, in other words, making a choice by evaluating based on two or more criteria (Çelikyay, 2002). MCDM techniques are used to keep the decision mechanism under control and arrive at a solution as quickly and readily as possible in decision-making problems where there are several alternatives and criteria (Orhan, 2013). Upon reviewing the literature, it is evident that MCDM techniques fall into two categories: "weighting" and "ranking". In this study, a new integrated criteria weighting approach was proposed using LBWA (Level Based Weight Assessment), CRITIC (The Criteria Importance Through Intercriteria Correlation) and SOWIA (Subjective and Objective Weight Integrated Approach) methods from the MCDM weighting methods.

In the proposed integrated weighting approach; the LBWA method was chosen to weight the criteria to be used in determining demand priority based on expert opinions. The LBWA method was developed by Žižović and Pamučar (2019) and was used to determine weight coefficients for evaluating supplier performances. LBWA, a subjective weighting method based on the principle of pairwise comparison, achieves importance weights by grouping decision criteria and evaluating the criteria in each group with a simple algorithm. The CRITIC method proposed by Diakoulaki, Mavrotas and Papayannakis (1995) was developed due to the need for an objective criterion weighting method and was used in the selection of Greek pharmaceutical companies. CRITIC is an objective weighting method that eliminates the influence of decision makers on the decision and produces results by acting directly on the data. The SOWIA was first used by Das, Sarkar and Ray (2013) along with the MOORA (Multi-Objective Optimization by Ratio Analysis) method for performance evaluation and ranking of seven Indian Institutes of Technology. SOWIA, on the other hand, is a combined weighting method that allows a single weight to be obtained by considering both objective and subjective criteria weights. With the integrated approach created using these three methods, the importance weights of the criteria to be considered in determining the production priority were determined and their order of importance was revealed. Customer demand priority can be determined by using the order of importance of the criteria.

In a company operating in the ceramics industry, an integrated weighting approach consisting of three stages was applied to determine production priority according to customer characteristics. The ceramics company exports floor and wall ceramics, glazed porcelain and technical granite. Production demands brought about by the rapidly increasing customer portfolio in recent years have remained above the operating capacity. This situation has created the need to prioritize customer demands.

Although there are many studies in the MCDM literature, there are few studies that determine production priorities. Furthermore, there is no other study in the literature that considers both subjective and objective approaches simultaneously and determines the weights of the criteria for demand prioritization. It is believed that this study will ultimately make a valuable contribution to the literature.

## 2.Literature Review

LBWA and CRITIC methods are effective in determining subjective and objective weights. Therefore, this paper integrates the weights obtained from LBWA and CRITIC methods using the SOWIA method to obtain a comprehensive weight. So far, only the study conducted by Wang, Chen, Wang, Deveci, Moslem and Coffman (2024) has attempted to reveal the obstacles to the implementation of digital transformation in the energy sector by using these three methods together.

LBWA method has been applied for many real-world problems in business economics, defence, and environment-related areas (Ayan, Abacıoğlu and Basilio, 2023), namely, data literacy evaluation (Zeng, Gao and Wu, 2024), planning off-grid hybrid energy system (Ali, Sunny, Aghaloo and Wang, 2024), public transportation (Pamučar, Gokasar, Torkayesh, Deveci, Martínez and Wu, 2023), site selection of direct current microgrid-based hydrogen-electric hybrid refueling stations (Zhu, Lei, and Gao, 2023), assessing the barriers to the use of digital technologies (Sharma, Joshi and Govindan, 2023), supplier selection problem (Ayough, Shargh and Khorshidvand, 2023), container port selection (Pamučar and Görçün, 2022), evaluation of leanness of micro, small and medium enterprises (Biswas, Pamučar, Božanic and Halder, 2022a), equity linked savings scheme funds selection (Biswas, Pamučar and Mukhopadhyaya, 2022b), sustainable food supplier selection (Yazdani, Pamučar, Chatterjee and Torkayesh, 2022), evaluation of waste in fast-moving consumer goods (Ögel, Ecer and Özgöz, 2022), assessment of Ideal Smart Network Strategies (Korucuk, Aytekin, Ecer, Pamučar and Karamaşa, 2022), supplier selection in the railway sector (Uluskan, Topuz and Çimen, 2022), renewable energy resources (Ecer, Pamučar, Mardani, Alrasheedi, 2021), smart cities (Adali, Öztaş, Öztaş and Tuş, 2022), weapon system selection (Hristov, Pamučar and Amine, 2021), evaluation of healthcare sectors (Torkayesh, Pamučar, Ecer and Chatterjee, 2021), evaluation of human resources in transportation companies (Jakovljevic, Zizovic, Pamučar, Stevic and Albijanic, 2021), evaluation of sustainable energy policies in the agricultural sector (Pamučar, Behzad, Božanić and Behzad, 2021), assessment of information and communication technology development criteria of G7 countries (Torkayesh and Torkayesh 2021), location selection for the camp (Božanic, Jurišic and Erkic, 2020a), sustainable reorganization of a healthcare system (Pamučar, Žižović, Marinković, Doljanica, Jovanović and Brzaković, 2020), facility location selection (Biswas and Pamučar, 2020) and weapon selection (Božanic, Ranđelović, Radovanović and Tešić, 2020b).

A growing body of literature on applying CRITIC in various sectors has resulted from practitioners and scholars realizing how important it is to use it to address complex problems across several domains (Farid, Miletic, Riaz, Simic and Pamučar, 2024; Krishnan, 2024). Researchers have been using CRITIC to seek solutions for many real-world problems, such as marine port selection (Görçün and Küçükönder, 2021), indoor air quality criteria assessment (Piasecki and Kostyrko, 2020), the appraisal of financial risk (Peng and Huang, 2020), the development of electrical charging retailers for electric automobiles (Wei, Lei, Lin, Wang, Wei, Wu and Wei, 2020), software selection (Tus and Adalı, 2019), assessing a manufacturing shop floor (Kumari and Kulkarni, 2019), risk assesstment (Ayrım and Can, 2017). Additionally, it is seen in the literature that CRITIC is also used in current issues such as COVID-19 and Industry 4.0 (Erdogan and Ayyildiz, 2022; Shang, Saeidi and Goh, 2022; Delice and Keskin 2023; Gupta, Kushwaha, Badhera and Singh, 2024; Razzaq, Riaz and Aslam, 2024).

The SOWIA has been used in many studies as it helps determine the relative importance of criteria by integrating the perception and understanding of different experts in the form of subjective and objective weights depending on the performance of the alternatives on each criterion (Das, 2013). For example, the sustainability strategy selection (Sreekumar and Rajmohan, 2019), identifying key barriers to the adoption of Digital Twins and Blockchain in Industrial Internet of Things (Li, Su and Mardani, 2023), assessment of sustainable energy storage systems (Narayanamoorthy, Brainy, Shalwala, Alsenani, Ahmadian and Daekook, 2023) sustainable biomass crop selection (Mishra, Rani, Pratibha Ravi Sundar Prajapati, 2021a), selecting the ideal sustainable green strategy (Aytekin, Korucuk, Bedirhanoğlu and Vladimir, 2024), assessment of bio-medical waste disposal methods (Narayanamoorthy, Annapoorani, Kang, Baleanu, Jeon, Kureethara and Ramya, 2020), optimal site selection of electric vehicle charging station (Mishra, Rani and Saha, 2021b), determining the effectiveness of countries in combating pandemics (Keskin and Delice, 2023) is used SOWIA method.

As a result, when looking at the literature, it is seen that these three techniques are applied together with different MCDM techniques for solving decision-making problems in various fields. Because employing several MCDM techniques to solve a decision problem will contribute to the production of more compromised outcomes.

# 3.Methods

## 3.1. LBWA method

The LBWA method is a subjective weighting method based on the principle of pairwise comparison and is used to determine the criteria weights. The LBWA method was developed with the idea of creating a mathematical model that eliminates inconsistency and provides solutions with fewer pairwise comparisons than other subjective criteria weighting methods. The advantages of the LBWA method are as follows:

(1) The LBWA model can be used to calculate weight coefficients with a small number of criteria comparisons—just n–1 comparisons,
(2) The LBWA model algorithm does not grow more complex as the number of criteria increases, making it appropriate for use in complex MCDM models with a large number of evaluation criteria, a
(3) The LBWA model enables decision makers to show their preferences when prioritizing criteria through a logical algorithm. By using the LBWA model, inconsistent expert preferences which are allowed in some subjective models (Best Worst Method and Analytic Hierarcy Process) are eliminated, yielding optimal weight coefficient values through a straightforward mathematical process;
(4) The model's flexibility lies in its ability to utilize all values from the predefined scale, meaning that it is not restricted to integer values inside the given interval.

The flexibility of the LBWA model in terms of extra corrections of weight coefficient values by the elasticity coefficient ($r_0$) must be emphasized in addition to the other advantages. Decision-makers can further modify weight coefficient values based on their personal preferences thanks to the elasticity coefficient. Furthermore, by characterizing the impact of altering the criteria weight coefficients on the ultimate decision, the elasticity coefficient permits an investigation of the MCDM model's robustness. The steps for calculating criteria weights with the LBWA method are as follows (Žižović and Pamučar, 2019; Ayçin, 2023):

First, the decision maker determines the most important criterion in the set of criteria $S = \{C_1, C_2, \dots, C_n\}$. For example, let the most important criterion determined by the decision maker be the criterion $C_1$. Then, the decision maker creates criteria subsets by considering the most important criterion as described below:

Level $S_1$: The most important criterion must be either equally essential or at most twice as important as the criteria in this group.

Level $S_2$: The most important criterion must be at least 2 times and at most 3 times more important than the criteria in this group.

Level $S_3$: The most important criterion must be at least 3 times and at most 4 times more important than the criteria in this group.

Level $S_k$: The most important criterion must be at least k times more important and at most k+1 times more important than the criteria in this group (Demir, 2020).

By applying the rules mentioned above, decision-makers determine the rough classification of the criteria and group the criteria according to their level of importance. If the significance of the criterion $C_j$ is denoted by $s(C_j)$, where $j \in \{1,2,\dots,n\}$, then we have $S = S_1 \cup S_2 \cup \dots \cup S_k$, where for every level $i \in \{1,2,\dots,k\}$, the Equation (1) applies.

$$S_i = \{C_{i_1}, C_{i_2}, \dots, C_{i_s}\} = \{C_j \in S: i \leq s(C_j) < i+1\} \quad (1)$$

Within the formed levels of the influence of the criteria it is performed the comparison of criteria by their significance. Each criterion $C_{i_p} \in S_i$ in the level $S_i = \{C_{i_1}, C_{i_2}, \dots, C_{i_s}\}$ is assigned with an integer $I_{i_p} \in \{0,1,2,\dots,r\}$ such that the most important criterion $C_1$ is assigned with $I_1 = 0$, and if $C_{i_p}$ is more significant than $C_{i_q}$ then $I_p < I_q$, and if $C_{i_p}$ is equivalent to $C_{i_q}$ then $I_p = I_q$. Where the maximum value on the scale for the comparison of criteria is defined by applying the expression (2)

$$r = max\{|S_1|, |S_2|, \dots, |S_k|\} \quad (2)$$

The elasticity coefficient is obtained according to the r value determined according to Equation (2). $r_0$, defined as the elasticity coefficient, is determined by the $r_0 > r$ ($r_0 \in R$). The influence function $f: S \rightarrow R$ is defined as in Equation (3).

$$f\left(C_{i_p}\right) = \frac{r_0}{i \cdot r_0 + I_{i_p}} \tag{3}$$

Where i is the level number in which the criterion is classified; $r_0$ is the elasticity coefficient; $I_{i_p}$ indicates the integer value assigned to criterion $C_{i_p}$ within the relevant level.

The weight of the most important criterion is determined by using equation (4). Then, the weights of the other criteria is obtained using Equation (5).

$$w_i = \frac{1}{f(C_1)+f(C_2)+\cdots+f(C_2)+\cdots+f(C_n)} \tag{4}$$

$$w_j = f(C_i) \cdot w_i \tag{5}$$

## 3.2. CRITIC method

The CRITIC approach eliminates the influence of decision makers on the decision because the end result is the use of actual data for operations. Both the standard deviation of a criterion and its correlation with other criteria serve as the foundation for objectively calculating the criteria weights. Thus, the variability of the criteria and the degree and direction of the relationships between the criteria determine the criteria weights (Ecer, 2020). The CRITIC method can be used to calculate criteria weights in the following steps:

The initial decision matrix is created as in Equation (6) using numerical data regarding the criteria to be used in decision making.

$$X = \begin{bmatrix} x_{11} & x_{21} & \cdots & x_{i1} \\ x_{12} & x_{22} & \cdots & x_{i2} \\ \cdots & \cdots & \cdots & \cdots \\ x_{1n} & x_{2n} & \cdots & x_{in} \\ \cdots & \cdots & \cdots & \cdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \tag{6}$$

Where $x_{ij}$ represents the value of *ith* alternative (i=1, 2, …, m) for *jth* criterion (j=1, 2, …, n).

Benefit and cost criteria are standardized with the help of linear normalization. Equation (7) and Equation (8) are used to normalize the benefit and cost criteria, respectively, and a normalized decision matrix is created.

$$r_{ij} = \frac{x_{ij} - x_{jmin}}{x_{jmak} - x_{jmin}} \tag{7}$$

$$r_{ij} = \frac{x_{jmak} - x_{ij}}{x_{jmak} - x_{jmin}} \tag{8}$$

Where $r_{ij}$; the *ith* alternative is the normalized value of $x_{ij}$ according to the *jth* criterion.

The standard deviation of the criteria is obtained with Equation (9).

$$\sigma_j = \sqrt{\frac{\sum_{i=1}^{n}\left(r_{ij}-\underline{r_{ij}}\right)^2}{n-1}} \tag{9}$$

Where $\underline{r_{ij}}$ shows the average value of $r_{ij}$ and $\sigma_j$ shows the standard deviation of the jth criterion.

The correlation coefficient is calculated by using the values obtained as a result of normalization in Equation (10). $P_{jk}$ indicates the correlation value between criterion j and criterion k.

$$P_{jk} = \frac{\sum_{i=1}^{m}\left(r_{ij}-\underline{r_j}\right)\cdot\left(r_{ik}-\underline{r_k}\right)}{\sqrt{\sum_{i=1}^{m}\left(r_{ij}-\underline{r_j}\right)^2\cdot\sum_{i=1}^{m}\left(r_{ik}-\underline{r_k}\right)^2}} \tag{10}$$

Finally, the criterion weight is calculated according to Equation (11). When specified as $\sigma_j \cdot \sum_{k=1}^{n}\left(1-P_{jk}\right)_j = C_j$, it can be simplified as stated in Equation (12).

$$w_j = \frac{\sigma_j \cdot \sum_{k=1}^{n}\left(1-P_{jk}\right)}{\sum_{k=1}^{n}\left(\sigma_j \cdot \sum_{k=1}^{n}\left(1-P_{jk}\right)\right)} \tag{11}$$

$$w_j = \frac{C_j}{\sum_{k=1}^{n} C_k} \tag{12}$$

## 3.3. SOWIA method

Criteria weights obtained by subjective and objective weighting methods are integrated with the SOWIA in 3 steps. The initial decision matrix created in the first step is normalized as shown in Equation (6). In the second step; criteria weights are determined using the normalized matrix according to the established MCDM method. While introducing the method, Zaher, Khalifa and Mohamed (2018) used the Entropy method as the objective method and the RR (Rank Reciprocal) weighting method, which is based on the decision maker interpreting and ranking the criteria in order of importance, as the subjective method. Since normalization and criterion weight determination calculations will be different for each method, special formulations are not given in the first and second steps. If the objective and subjective criteria weights are available to the decision maker, steps 1 and 2 should be skipped and the method should be continued directly from the third step.

In the third step of the SOWIA method; the integrated criterion weight is calculated using Equation (13), including the criterion weight $O_j$ obtained by the objective method, the criterion weight $S_j$ obtained by the subjective method, and the combination of objective and subjective weights $W_j^{int}$.

$$W_j^{int} = \alpha \cdot O_j + (1-\alpha) \cdot S_j \tag{13}$$

α is the objective decision weight and takes a value in the range (0,1).

## 3.4.Proposed Integrated Criteria Weighting Approach

The integrated approach to production priority determination suggested in this study comprises three processes, as shown in Figure 1.

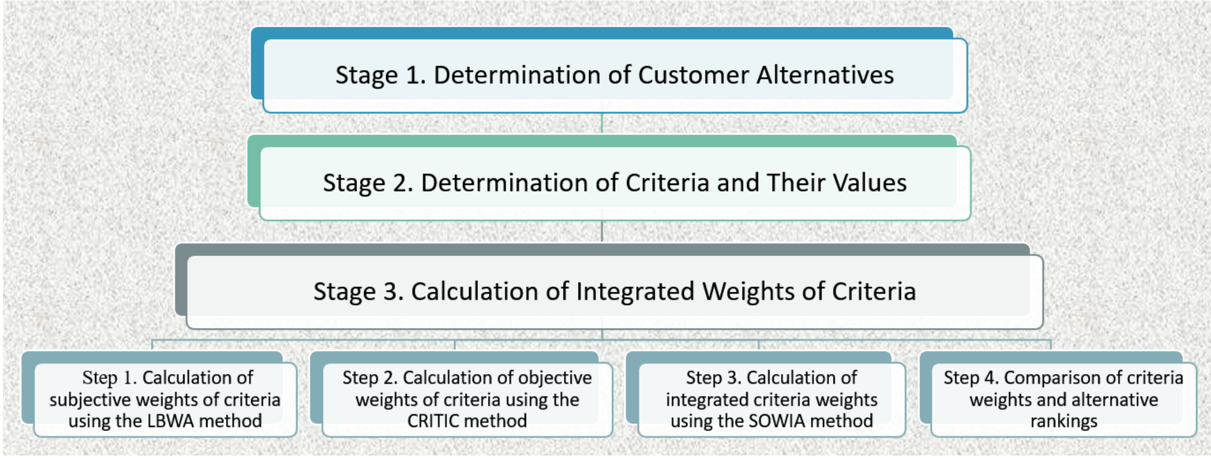


**Figure 1.** Flowchart of the proposed integrated approach

As seen in Figure 1, customer alternatives are determined in the first stage. In the second stage, the criteria that will affect the production priority depending on customer alternatives are determined by the decision-makers working in the enterprise. In the third stage, criteria weights obtained both subjectively and objectively by the LBWA and CRITIC methods are combined using the SOWIA method to obtain integrated criteria weights. Finally, the weights obtained from subjective, objective, and integrated criteria weighting methods are compared. Thus, the most important criteria to be used in determining the customer to whom production priority will be given are determined.

## 4. Application

In this study, the criteria used to determine customer priority in a company that exports ceramics are prioritized with the proposed integrated criteria weighting approach. Permission was obtained from company officials for this study, but company executives did not allow the company name to be shared. In the company; The Export Planning and Tracking department should manage demand and stock in a way that increases customer satisfaction and business profitability, considering the technical conditions of the factories. The production plan prepared by the factory is created by taking into consideration various parameters such as customer priority, product cost, production capacity, as well as technical constraints in the business. For demand management that depends on more than one criterion, customer priority must be determined, which is of great importance at the planning stage. The proposed approach was implemented in three stages as shown in Figure 1.

**Stage 1. Determination of customer alternatives**

The company in question has approximately 50 customers to whom it actively sells. Among these customers, the 22 customers with the highest product demand were taken into account. For customer privacy, customer names are not shared and are referred to as $M_1$, $M_2$...$M_{22}$.

**Stage 2. Determination of criteria and their values**

Seven criteria that will affect business profitability and will be used to determine production priorities were established by six experts. These criteria are as follows:

**Average Selling Price ($C_1$):** It is the sales price given to the customer.

**Stock ($C_2$):** It refers to the stock produced for the customer and waiting in the factory.

**Demand Amount($C_3$):** Demand quantity refers to the total amount of products that the customer states she will purchase in 2022.

**Sales Amount ($C_4$):** The total sales amount made to the customer in 2021.

**Payment Performance ($C_5$):** It refers to the customer's payment performance after receiving the product.

**Penalty Deadline Period ($C_6$):** The period during which the product must be delivered on the deadline determined by the customer. The business is fined for each day that this period passes. Customers whose penalty period is stated as 600 in Table 1 do not have any criminal sanctions, but the period is entered into the Canias ERP system as 600 days, which is 1.5 years.

**Stock Conversion Rate ($C_7$):** It varies depending on the time the customer purchases the product. It indicates how many days the product is kept in stock.

The average selling price is a benefit criterion that should be considered when assessing customer priority since it boosts business profitability and gives precedence to customers who have the highest selling price. Likewise, demand amount, sales amount, and payment performance criteria are also benefit criteria. Stock, penalty delivery time, and stock conversion rate criteria are cost criteria, and minimizing these values will positively affect customer priority. The criterion values shown in Table 1 were obtained using the data in the Canias ERP program of the 22 customers to whom the company sells the most.

**Table 1.** Criteria and their values

| | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ | $C_6$ | $C_7$ |
|---|---|---|---|---|---|---|---|
| | ($) | ($m^2$) | ($m^2$) | ($m^2$) | (%) | (Day) | (%) |
| | $max$ | $min$ | $max$ | $max$ | $max$ | $min$ | $min$ |
| $M_1$ | 9,16 | 30.000 | 664.054 | 660.000 | 88 | 600 | 43 |
| $M_2$ | 11,00 | 25.000 | 628.535 | 600.000 | 85 | 60 | 30 |
| $M_3$ | 10,00 | 3.334 | 576.900 | 580.000 | 95 | 600 | 18 |
| $M_4$ | 12,00 | 15.614 | 524.282 | 510.000 | 65 | 600 | 35 |
| $M_5$ | 9,00 | 10.000 | 612.964 | 459.000 | 70 | 600 | 50 |
| $M_6$ | 12,48 | 15.000 | 448.452 | 400.000 | 55 | 600 | 45 |
| $M_7$ | 12,00 | 2.000 | 344.228 | 390.000 | 90 | 600 | 15 |
| $M_8$ | 8,58 | 35.000 | 660.284 | 350.000 | 65 | 600 | 60 |
| $M_9$ | 9,86 | 1.500 | 344.377 | 350.000 | 86 | 60 | 45 |
| $M_{10}$ | 7,37 | 18.375 | 359.709 | 350.000 | 95 | 600 | 25 |
| $M_{11}$ | 7,88 | 3.000 | 343.094 | 343.000 | 90 | 60 | 15 |
| $M_{12}$ | 8,50 | 10.080 | 330.990 | 330.000 | 98 | 60 | 10 |
| $M_{13}$ | 12,30 | 5.000 | 317.873 | 317.870 | 96 | 120 | 10 |
| $M_{14}$ | 12,00 | 28.500 | 291.458 | 300.000 | 98 | 60 | 20 |
| $M_{15}$ | 5,43 | 25.000 | 313.414 | 290.000 | 98 | 600 | 35 |
| $M_{16}$ | 6,90 | 16.765 | 288.410 | 280.000 | 75 | 60 | 35 |
| $M_{17}$ | 8,24 | 503 | 268.207 | 260.000 | 85 | 60 | 30 |
| $M_{18}$ | 11,00 | 10.000 | 281.152 | 250.000 | 85 | 60 | 20 |
| $M_{19}$ | 8,80 | 5.899 | 218.747 | 218.000 | 95 | 60 | 15 |
| $M_{20}$ | 12,00 | 2.500 | 206.863 | 210.000 | 70 | 600 | 20 |
| $M_{21}$ | 12,22 | 12.474 | 223.209 | 190.500 | 78 | 100 | 50 |
| $M_{22}$ | 7,65 | 14.417 | 189.758 | 189.000 | 85 | 100 | 25 |

**Stage 3. Calculation of Integrated Weights of Criteria**

**Step 1. Calculation of subjective weights of criteria using the LBWA method**

First, the order of importance of the criteria is determined. Criteria are scored as 1-highest and 9-lowest. The most important criteria for decision makers were determined by sales amount ($C_4$) and average selling price ($C_1$). Experts assigned scores, as indicated in Table 2.

**Table 2.** Order of importance of criteria

| $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ | $C_6$ | $C_7$ |
|---|---|---|---|---|---|---|
| 1 | 2 | 5 | 1 | 4 | 3 | 9 |

After the importance of the criteria is determined, the criteria are compared pairwise and ranked from most important to least important. This ranking made by decision makers is shown in Table 3.

**Table 3.** Sorting criteria according to their importance

| $C_1$ | $C_4$ | $C_2$ | $C_6$ | $C_5$ | $C_3$ | $C_7$ |
|---|---|---|---|---|---|---|
| 1 | 1 | 2 | 3 | 4 | 5 | 9 |

As seen in Table 3, the most important criterion was determined to be sales amount $(C_4)$. Decision makers created subsets of criteria:

*Level $S_1$:* The most important criterion $C_4$ is of equal importance to the $C_1, C_4, C_5, C_6$.

$$S_1 = \{C_1, C_4, C_5, C_6\}$$

*Level $S_2$:* The most important criterion $C_4$ is at least twice and at most three times more important than the $C_2, C_3, C_7$.

$$S_2 = \{C_2, C_3, C_7\}$$

Then, the criteria are compared with each other and integer assignment is made according to their importance levels. The most important criterion, $C_4$, was assigned a value of 0. Then integer value assignment, the maximum integer value assigned is found. Equation (2) is used for this process.

$$S_1 = \{C_1, C_4, C_5, C_6\}, \qquad S_2 = \{C_2, C_3, C_7\}$$

$$r = max\{4,3\} = 4$$

According to the r value, the elasticity coefficient is determined from the $r_0 > r$ equation as $r_0 > 4$. i.e. $r_0 = 5$. Impact functions for each level were calculated as follows using Equation (3) and shown in Table 4.

$$f(C_{1_5}) = \frac{5}{1 \cdot 5 + 1} = 0{,}833$$

**Table 4.** Influence functions

| | |
|---|---|
| $f(C_{1_4})$ | 1,000 |
| $f(C_{1_1})$ | 0,625 |
| $f(C_{1_5})$ | 0,833 |
| $f(C_{1_6})$ | 0,714 |
| $f(C_{2_2})$ | 0,455 |
| $f(C_{2_3})$ | 0,417 |
| $f(C_{2_7})$ | 0,385 |

The criteria weights are calculated using Equation (4) and Equation (5). First, the weight of the most important criterion is determined. Then other criteria weights are calculated. Table 5 shows the weights determined for all criteria. The $w_4$ and $w_5$ values of criteria $C_4$ and $C_5$ , which are determined as the most important criteria, are calculated as follows:

$$w_4 = \frac{1}{1 + 0{,}625 + \ldots + 0{,}385} = 0{,}226$$

$$w_5 = 0{,}833 \cdot 0{,}226 = 0{,}188$$

. **Table 5.** Criteria weights determined according to LBWA Method

| | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ | $C_6$ | $C_7$ |
|---|---|---|---|---|---|---|---|
| $w_j$ | 0,141 | 0,103 | 0,094 | 0,226 | 0,188 | 0,161 | 0,087 |
| Rank | 4 | 5 | 6 | 1 | 2 | 3 | 7 |

As seen in Table 5, according to the LBWA method, the sales amount ($C_4$) criterion with the highest weight score of 0.226 was determined as the most important criterion, and the least important criterion was determined as the stock conversion ratio ($C_7$). It was stated that the resulting ranking was meaningful when evaluated together with experts. It has been interpreted that the importance of other criteria is also low for a customer with a low sales volume. Furthermore, it makes sense to give this criterion more weight than others because a customer with poor payment behavior will not generate much profit for the company. The company should give priority to customers with low penalty periods among customers with good sales volume and payment performance. Therefore, experts have confirmed that this criterion is in third place. Experts state that the sales price is among the other crucial factors that will boost a company's profitability. A customer who does not have a stock of products produced and ready for shipment is more valuable than a customer whose demand is high and whose stock is not yet converted to shipment because it does not generate any stock cost to the business. Therefore, the ranking of this criterion was considered appropriate.

**Step 2. Calculation of objective weights of criteria using the CRITIC method**

In this step, the initial decision matrix must first be created. In this content, the values given in Table 1 were used to create the initial decision matrix. The initial decision matrix was normalized using Equations (7) and (8), and the normalized decision matrix was obtained as shown in Table 6.

**Table 6.** Normalized decision matrix

| | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ | $C_6$ | $C_7$ |
|---|---|---|---|---|---|---|---|
| $M_1$ | 0,529 | 0,145 | 1,000 | 1,000 | 0,767 | 0 | 0,340 |
| $M_2$ | 0,790 | 0,290 | 0,925 | 0,873 | 0,698 | 1,000 | 0,600 |
| $M_3$ | 0,648 | 0,918 | 0,816 | 0,830 | 0,930 | 0 | 0,840 |
| $M_4$ | 0,932 | 0,562 | 0,705 | 0,682 | 0,233 | 0 | 0,500 |
| $M_5$ | 0,506 | 0,725 | 0,892 | 0,573 | 0,349 | 0 | 0,200 |
| $M_6$ | 1,000 | 0,580 | 0,545 | 0,448 | 0 | 0 | 0,300 |
| $M_7$ | 0,932 | 0,957 | 0,326 | 0,427 | 0,814 | 0 | 0,900 |
| $M_8$ | 0,447 | 0 | 0,992 | 0,342 | 0,233 | 0 | 0 |
| $M_9$ | 0,628 | 0,971 | 0,326 | 0,342 | 0,721 | 1,000 | 0,300 |
| $M_{10}$ | 0,275 | 0,482 | 0,358 | 0,342 | 0,930 | 0 | 0,700 |
| $M_{11}$ | 0,347 | 0,928 | 0,323 | 0,327 | 0,814 | 1,000 | 0,900 |
| $M_{12}$ | 0,435 | 0,722 | 0,298 | 0,299 | 1,000 | 1,000 | 1,000 |
| $M_{13}$ | 0,975 | 0,870 | 0,270 | 0,274 | 0,953 | 0,889 | 1,000 |
| $M_{14}$ | 0,932 | 0,188 | 0,214 | 0,236 | 1,000 | 1,000 | 0,800 |
| $M_{15}$ | 0 | 0,290 | 0,261 | 0,214 | 1,000 | 0 | 0,500 |
| $M_{16}$ | 0,209 | 0,529 | 0,208 | 0,193 | 0,465 | 1,000 | 0,500 |
| $M_{17}$ | 0,398 | 1,000 | 0,165 | 0,151 | 0,698 | 1,000 | 0,600 |
| $M_{18}$ | 0,790 | 0,725 | 0,193 | 0,130 | 0,698 | 1,000 | 0,800 |
| $M_{19}$ | 0,478 | 0,844 | 0,061 | 0,062 | 0,930 | 1,000 | 0,900 |
| $M_{20}$ | 0,932 | 0,942 | 0,036 | 0,045 | 0,349 | 0 | 0,800 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| $M_{21}$ | 0,963 | 0,653 | 0,071 | 0,003 | 0,535 | 0,926 | 0,200 |
| $M_{22}$ | 0,315 | 0,597 | 0 | 0 | 0,698 | 0,926 | 0,700 |

Standard deviation ($\sigma_j$) values of the criteria were calculated with Equation (9) and shown in Table 7.

**Table 7.** Standard deviation values

| | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ | $C_6$ | $C_7$ |
|---|---|---|---|---|---|---|---|
| $\sigma_j$ | 0,295 | 0,297 | 0,328 | 0,282 | 0,290 | 0,499 | 0,288 |

Then, the correlation coefficients of the criteria were calculated using Equation (10). Correlation values ($P_{jk}$) are given in Table 8.

**Table 8.** Correlation values of criteria

| | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ | $C_6$ | $C_7$ |
|---|---|---|---|---|---|---|---|
| $C_1$ | 1,000 | 0,178 | 0,045 | 0,131 | -0,295 | -0,041 | 0,073 |
| $C_2$ | 0,178 | 1,000 | -0,463 | -0,282 | 0,122 | 0,224 | 0,471 |
| $C_3$ | 0,045 | -0,463 | 1,000 | 0,884 | -0,296 | -0,516 | -0,469 |
| $C_4$ | 0,131 | -0,282 | 0,884 | 1,000 | -0,065 | -0,439 | -0,185 |
| $C_5$ | -0,295 | 0,122 | -0,296 | -0,065 | 1,000 | 0,364 | 0,652 |
| $C_6$ | -0,041 | 0,224 | -0,516 | -0,439 | 0,364 | 1,000 | 0,325 |
| $C_7$ | 0,073 | 0,471 | -0,469 | -0,185 | 0,652 | 0,325 | 1,000 |

$(1 - P_{jk})$ calculations to be used to find the importance weights of the criteria are given in Table 9.

**Table 9.** $(1 - P_{jk})$ values

| | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ | $C_6$ | $C_7$ |
|---|---|---|---|---|---|---|---|
| $C_1$ | - | 0,822 | 0,955 | 0,869 | 1,295 | 1,041 | 0,927 |
| $C_2$ | 0,822 | - | 1,463 | 1,282 | 0,878 | 0,776 | 0,529 |
| $C_3$ | 0,955 | 1,463 | - | 0,116 | 1,296 | 1,516 | 1,469 |
| $C_4$ | 0,869 | 1,282 | 0,116 | - | 1,065 | 1,439 | 1,185 |
| $C_5$ | 1,295 | 0,878 | 1,296 | 1,065 | - | 0,636 | 0,348 |
| $C_6$ | 1,041 | 0,776 | 1,516 | 1,439 | 0,636 | - | 0,675 |
| $C_7$ | 0,927 | 0,529 | 1,469 | 1,185 | 0,348 | 0,675 | - |
| Total | 5,908 | 5,749 | 6,814 | 5,956 | 5,518 | 6,083 | 5,132 |

The final importance weights were calculated with the help of Equations (11)-(12) and are shown in Table 10.

**Table 10.** Criteria weights determined according to CRITIC Method

| | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ | $C_6$ | $C_7$ |
|---|---|---|---|---|---|---|---|
| $w_j$ | 0,129 | 0,127 | 0,166 | 0,125 | 0,119 | 0,225 | 0,110 |
| Rank | 3 | 4 | 2 | 5 | 6 | 1 | 7 |

As seen in Table 10 illustrates, according to experts, the penal deadline period ($C_6$) is the most crucial factor since, even in cases where the deadline is short, a client who is ignored hurts the firm and reduces profit. The stock conversion ratio ($C_7$) is the least significant criteria.

**Step 3. Calculation of integrated criteria weights using the SOWIA method**

In steps 1 and 2, the importance rankings of the criteria obtained using the LBWA and CRITIC methods differed. While the order of importance of the sales amount ($C_4$) criterion is in first place with the LBWA method, it was ranked fifth by the CRITIC method. Considering this difference in criterion importance weights and rankings, a single weight and importance order was determined for each criterion with the SOWIA method in the final stage.

In this study, the criteria weights obtained with the CRITIC method were accepted as $(O_J)$ obtained with the objective method. The criteria weights obtained with the LBWA method were accepted as $(S_J)$ obtained with the subjective method. In this context, integrated weights were obtained using Equation (13). Table 11 shows the comparison of the criteria weights determined according to different α values. Thus, the most appropriate α value was tried to be determined.

**Table 11.** Selection of α value (0.2,0.4,0.6 or 0.8) according to criteria weights in SOWIA

| | $W_{0.2}$ | $W_{0.4}$ | $W_{0.6}$ | $W_{0.8}$ |
|---|---|---|---|---|
| $C_1$ | **0.139** | **0.136** | 0.134 | **0.132** |
| $C_2$ | 0.107 | 0.112 | 0.117 | 0.122 |
| $C_3$ | 0.101 | 0.123 | **0.137** | **0.152** |
| $C_4$ | **0.206** | **0.185** | **0.165** | **0.145** |
| $C_5$ | **0.181** | **0.160** | **0.146** | 0.132 |
| $C_6$ | 0.174 | **0.187** | **0.200** | **0.212** |
| $C_7$ | 0.091 | 0.096 | 0.101 | 0.105 |

The penalty deadline period ($C_6$) is typically the first criterion to be considered when assessing the criteria listed in Table 13, followed by sales amount ($C_4$). The customer with the best payment performance should be prioritized when comparing customers with the same sales volume. In this case, α=0.2 and α=0.8 are excluded. Then when comparing two customers with good payment performance ($C_5$), priority should be given to the customer with a higher selling price ($C_1$). Thus, the value α=0.4 has been determined by decision makers as the most appropriate value for this problem. Accordingly, the integrated criteria weights $W_j^{int}$ obtained by the SOWIA are given in Table 12.

**Table 12.** Criteria weights and rankings calculated with the SOWIA for α=0.4

| | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ | $C_6$ | $C_7$ |
|---|---|---|---|---|---|---|---|
| $W_j^{int}$ | 0,136 | 0,112 | 0,123 | 0,185 | 0,160 | 0,187 | 0,096 |
| Rank | 4 | 6 | 5 | 2 | 3 | 1 | 7 |

As seen in Table 12, the criterion with the highest importance according to the SOWIA was the penalty deadline criterion($C_6$), while the criterion with the lowest weight was the stock conversion ratio ($C_7$).

## Step 4. Comparison of criteria weights and rankings obtained from LBWA, CRITIC, and SOWIA methods

In this step, the priority orders of the criteria obtained according to the criteria weights determined by the LBWA, CRITIC, and SOWIA methods were compared. Thus, the criteria that should be taken into consideration first when determining the priority ranking of customer demands were determined. The comparison results are shown in Table 13.

**Table 13.** Comparison of criteria weights and importance rankings

| | $W_{LBWA}$ | $W_{CRITIC}$ | $W_{SOWIA}$ | LBWA Ranking | CRITIC Ranking | SOWIA Ranking |
|---|---|---|---|---|---|---|
| $C_1$ | 0,141 | 0,129 | 0,136 | 4 | 3 | 4 |
| $C_2$ | 0,103 | 0,127 | 0,112 | 5 | 4 | 6 |
| $C_3$ | 0,094 | 0,166 | 0,123 | 6 | 2 | 5 |
| $C_4$ | **0,226** | 0,125 | 0,185 | 1 | 5 | 2 |
| $C_5$ | 0,188 | 0,119 | 0,160 | 2 | 6 | 3 |
| $C_6$ | 0,161 | **0,225** | **0,187** | 3 | 1 | 1 |
| $C_7$ | 0,087 | 0,110 | 0,096 | 7 | 7 | 7 |

As seen in Table 13, according to the LBWA method, the most important criterion is the sales amount ($C_4$), and according to the CRITIC method, the most important criterion is the penalty deadline period($C_6$). According to the SOWIA method, the most important criterion is the ($C_6$), as in the CRITIC method. Whether the customer's order quantity is large or small, failure to deliver the product within the specified deadline will penalize the business. As long as the payment performance and sales price of customers with high sales volume are also good, business profitability will increase. Paying attention to the priority order of the criteria, especially the ($C_6$) and ($C_4$) criteria, can determine which customer's demand should be met first.

## 5. Conclusion and Recommendations

Nowadays, with the increasing competition conditions, maintaining customer satisfaction and loyalty has become very difficult. Businesses that want to increase customer satisfaction and therefore profitability need to determine customers' production priorities correctly to meet customer orders on time and effectively. Multiple conflicting criteria are effective in determining production priority. Because of this, the integrated weighting technique established using MCDM methodologies was utilized to calculate the importance weights and, consequently, the order of importance of the criteria to be employed in deciding the production priority. Which customer's request will be prioritized can be ascertained by looking at this sequence.

The integrated approach proposed in the study was used to determine the production priorities of a company operating in the ceramics industry. However, the proposed integrated weighting approach can also be applied to different sectors. In future studies, the approach proposed in this study can be developed by using different MCDM methods or various fuzzy-based MCDM methods in cases where information is incomplete and uncertain.

### Contribution of Authors

**Elif Kılıç Delice:** The methodology, supervision, and validation processes were managed, and the writing, reviewing, and editing of the manuscript were completed with care.
**Elif Akviran:** The investigation, data collection and curation, analysis, and writing of the manuscript were carried out.

### Conflicts of Interest

The authors declared that there is no conflict of interest.

## References

Adali, E.A., Öztaş, G.Z., Öztaş, T. & Tuş, A. (2022). Assessment of European Cities from a Smartness Perspective: An Integrated Grey MCDM Approach. *Sustainable Cities and Society.* 84, 104021. https://doi.org/10.1016/j.scs.2022.104021

Ali, T., Sunny, M.R., Aghaloo, K. & Wang, K. (2024). Planning off-grid hybrid energy system using techno-economic optimization and wins in league theory-based multi-criteria decision-making method in the wetland areas of developing countries. *Energy Conversion and Management,* 313, 118587. https://doi.org/10.1016/j.enconman.2024.118587

Ayan, B., Abacıoğlu, S. & Basilio, MP. A. (2023). A Comprehensive Review of the Novel Weighting Methods for Multi-Criteria Decision-Making. *Information,* 14(5), 285. https://doi.org/10.3390/info14050285

Ayçin, E. (2023). Çok Kriterli Karar Problemlerinde LBWA Yöntemi İle Kriterlerin Önem Ağırlıklarının Hesaplanmasına Yönelik Bir Uygulama: LBWA-Solver, İktısadı ve İdarı Bilimlerde Uluslararası Araştırma ve Değerlendirmeler, Serüven Yayınevi, 83-93. https://www.seruvenyayinevi.com/Webkontrol/uploads/Fck/iktisat1aralik2023_2.pdf

Ayough, A., Shargh, SB. & Khorshidvand, B. (2023). A new integrated approach based on base-criterion and utility additive methods and its application to supplier selection problem. *Expert Systems with Applications*, 221, 119740. https://doi.org/10.1016/j.eswa.2023.119740

Ayrım, Y., & Can, G. F. (2017). Risk değerlendirmesinde crıtıc metodu ile sektörlerin karşılaştırması. *Journal of Turkish Operations Management*, 1(1), 67-78.

Aytekin, A., Korucuk, S., Bedirhanoğlu, Ş.B. & Vladimir, S. (2024) Selecting the ideal sustainable green strategy for logistics companies using a T-spherical fuzzy-based methodology, *Engineering Applications of Artificial Intelligence,* 127, 107347. https://doi.org/10.1016/j.engappai.2023.107347

Bayram, E. (2022). *Talep yönetiminde üretim önceliğinin belirlenmesi için çok kriterli karar verme tabanlı bütünleşik bir yaklaşım* (Master's Thesis). Atatürk Universty, Erzurum. Retrieved from: https://tez.yok.gov.tr/UlusalTezMerkezi/tezDetay.jsp?id=NvNxiLfiIIp4n6IHVihaJA&no=M1kRqLG7j_tLf9e0KruXjA

Biswas, S. and Pamučar, D. (2020). Facility Location Selection for B-Schools in Indian Context: A Multi-Criteria Group Decision Based Analysis. *Axioms*, 9 (3): 77. https://doi.org/10.3390/axioms9030077

Biswas, S., Pamučar, D., Božanic, D. & Halder, B. (2022a). A New Spherical Fuzzy LBWA-MULTIMOOSRAL Framework: Application in Evaluation of Leanness of MSMEs in India. *Mathematical Problems in Engineering,* 1–17. https://doi.org/10.1155/2022/5480848

Biswas, S., Pamučar, D. & Mukhopadhyaya, J.N. (2022b). A Multi-Criteria-Based Analytical Study of the Impact of COVID-19 on ELSS Fund Performance. *International Journal of Management and Decision Making,* 21, 339–378. https://doi.org/10.1504/IJMDM.2022.10048438

Božanic, D., Jurišic, D. & Erkic, D. (2020a). LBWA–Z-MAIRCA Model Supporting Decision Making in the Army. *Operational Research in Engineering Sciences: Theory and Applications,* 3, 87–110. https://doi.org/10.31181/oresta2003087b

Božanić, D., Ranđelović, A., Radovanović & Tešić, M. D. (2020b). A hybrid LBWA- IR-MAIRCA multi-criteria decision-making model for determination of constructive elements of weapons. *Facta Universitatis-Series Mechanical Engineering,* 18 (3), 399-418. https://doi.org/10.22190/FUME200528033B

Çelikyay, S. (2002). *Çok amaçlı savaş uçağı seçiminde çok ölçütlü karar verme yöntemlerinin uygulanması* (Yüksek Lisans Tezi). Erişim adresi: https://tez.yok.gov.tr/UlusalTezMerkezi/tezSorguSonucYeni.jsp

Das, M.C., Sarkar, B. & Ray, S. (2013). On the performance of Indian technical institutions: a combined SOWIA-MOORA approach. *OPSEARCH*, 50(3), 319–333. https://doi.org/10.1007/s12597-012-0116-z

Demir, G. (2020). LBWA Method. Çok Kriterli Karar Verme Problemlerinde Kriter Ağırlıklandırma Yöntemleri, Nobel Yayınevi, Ankara, 137-158.

Diakoulaki, D., Mavrotas, G. & Papayannakis, L. (1995). Determining objective weights in multiple criteria problems: The CRITIC method. *Computers & Operations Research*, 22(7), 763-770. https://doi.org/10.1016/0305-0548(94)00059-H

Ecer, F. (2020). Çok Kriterli Karar Verme Geçmişten Günümüze Kapsamlı Bir Yaklaşım. Seçkin Yayıncılık, Ankara.

Ecer, F., Pamučar, D., Mardani, A. &Alrasheedi, M. (2021). Assessment of Renewable Energy Resources Using New Interval Rough Number Extension of the Level Based Weight Assessment and Combinative Distance-Based Assessment. *Renew Energy,* 170, 1156–1177. https://doi.org/10.1016/j.renene.2021.02.004

Erdogan, M. & Ayyildiz, E. (2022). Comparison of hospital service performances under COVID-19 pandemics for pilot regions with low vaccination rates, *Expert Systems with Applications*, 206, 117773. https://doi.org/10.1016/j.eswa.2022.117773

Farid, H.M.A., Miletic, S.D., Riaz, M., Simic, V. & Pamučar, D. (2024). Prioritization of sustainable approaches for smart waste management of automotive fuel cells of road freight vehicles using the q-rung orthopair fuzzy CRITIC-EDAS method. *Information Sciences*, 661, 120162. https://doi.org/10.1016/j.ins.2024.120162

Görçün, Ö.F. & Küçükönder, H. (2021). An integrated MCDM approach for evaluating the Ro-Ro marine port selection process: a case study in black sea region, *Australian Journal of Maritime & Ocean Affairs*, 13(3), 203-223. https://doi.org/10.1080/18366503.2021.1878872

Gupta, S., Kushwaha, P.S., Badhera, U. & Singh, R.K. (2024). Managing tourism and hospitality industry during pandemic: analysis of challenges and strategies for survival, *Benchmarking: An International Journal*, early access https://doi.org/10.1108/BIJ-11-2023-0806

Hristov, N., Pamučar, D. & Amine, M. (2021). Application of a D Number Based LBWA Model and an Interval MABAC Model in Selection of an Automatic Cannon for Integration into Combat Vehicles. *Defence Science Journal*, 71 (1), 34–45. https://doi.org/10.14429/dsj.71.15738

Jakovljevic, V., Zizovic, M., Pamučar, D., Stevic, Ž. & Albijanic, M. (2021). Evaluation of Human Resources in Transportation Companies Using Multi-Criteria Model for Ranking Alternatives by Defining Relations between Ideal and Anti-Ideal Alternative (RADERIA). *Mathematics,* 9 (9), 976. https://doi.org/10.3390/math9090976

Keskin, Z.B, & Delice E.K., (2023). Determining the effectiveness of countries in combating pandemics: COVID-19 case. *RAIRO Operations Research*,57, 2151–2176. https://doi.org/10.1051/ro/2023077

Krishnan, AR. (2024).Research trends in criteria importance through intercriteria correlation (CRITIC) method: a visual analysis of bibliographic data using the Tableau software, *Information Discovery And Delivery,* early access. https://doi.org/10.1108/idd-02-2024-0030

Korucuk, S., Aytekin, A., Ecer, F., Pamučar, D.S.S. & Karamaşa, Ç. (2022). Assessment of Ideal Smart Network Strategies for Logistics Companies Using an Integrated Picture Fuzzy LBWA–CoCoSo Framework. *Management Decision*, 61, 1434–1462. https://doi.org/10.1108/MD-12-2021-1621

Kumari, M., & Kulkarni, M. S. (2019).Single-Measure and Multi-Measure Approach of Predictive Manufacturing Control: A Comparative Study. *Computers & Industrial Engineering*, 127, 182–195. https://doi.org/10.1016/j.cie.2018.12.018

Li, Y., Su, D.A. & Mardani, A., (2023). Digital twins and blockchain technology in the industrial Internet of Things (IIoT) using an extended decision support system model: Industry 4.0 barriers perspective, *Technological Forecasting and Social Change,* 195, 122794. https://doi.org/10.1016/j.techfore.2023.122794

Mishra, A. R., Rani, Pratibha Ravi Sundar Prajapati (2021a). Multi-criteria weighted aggregated sum product assessment method for sustainable biomass crop selection problem using single-valued neutrosophic sets, *Applied Soft Computing,* 113, 108038. https://doi.org/10.1016/j.asoc.2021.108038

Mishra, AR, Rani, P & Saha, A. (2021b). Single-valued neutrosophic similarity measure-based additive ratio assessment framework for optimal site selection of electric vehicle charging station, *Internatıonal Journal of Intelligent System,* 36 (10), 5573-5604. https://doi.org/10.1002/int.22523

Narayanamoorthy, S., Annapoorani, V., Kang, D., Baleanu, D., Jeon, J., Kureethara, J.V. & Ramya, L. (2020). A novel assessment of bio-medical waste disposal methods using integrating weighting approach and hesitant fuzzy MOOSRA, *Journal of Cleaner Production,* 275, 122587. https://doi.org/10.1016/j.jclepro.2020.122587

Narayanamoorthy, S., Brainy, J.V., Shalwala, R.A., Alsenani, T.R., Ahmadian, A. & Daekook K., (2023). An enhanced fuzzy decision making approach for the assessment of sustainable energy storage systems. *Sustainable Energy, Grids and Networks,* 33, 100962. https://doi.org/10.1016/j.segan.2022.100962

Orhan, M. (2013). *Karar alma problemlerinde AHP'nin yeri ve kalkınmışlık kriterleriyle Avrupa Birliği üyesi ülkelerin karşılaştırılması* (Master's Thesis). Marmara Universty, İstanbul. Retrieved from: https://tez.yok.gov.tr/UlusalTezMerkezi/tezDetay.jsp?id=T0uALLN8tVzNEGdEm-taSA&no=EXwoGD24-wXNhSjuE-DyWw

Ögel, İ.Y., Ecer, F. & Özgöz, A.A. (2022). Identifying the Leading Retailer-Based Food Waste Causes in Different Perishable Fast-Moving Consumer Goods' Categories: Application of the F-LBWA Methodology. *Environmental Science and Pollution Research,* 30, 32656–32672. https: //doi.org/10.1007/s11356-022-24500-9

Pamučar, D., Žižović, M., Marinković, D., Doljanica, D., Jovanović, SV. & Brzaković P. (2020). Development of a Multi-Criteria Model for Sustainable Reorganization of a Healthcare System in an Emergency Situation Caused by the COVID-19 Pandemic. *Sustainability*, 12(18),7504. https://doi.org/10.3390/su12187504

Pamučar, D., Behzad, M. , Božanić, D. & Behzad, M. (2021). Decision making to support sustainable energy policies corresponding to agriculture sector: Case study in Iran's Caspian Sea coastline. *Journal of Cleaner Production,* 292, 125302. https://doi.org/10.1016/j.jclepro.2020.125302

Pamučar, D. & Görçün, Ö.F. (2022). Evaluation of the European Container Ports Using a New Hybrid Fuzzy LBWA-CoCoSo'B Techniques. *Expert Systems with Applications,* 203, 117463. https://doi.org/10.1016/j.eswa.2022.117463

Pamučar, D., Gokasar, I., Torkayesh, A.E., Deveci, M., Martínez, L. & Wu, Q. (2023). Prioritization of Unmanned Aerial Vehicles in Transportation Systems Using the Integrated Stratified Fuzzy Rough Decision-Making Approach with the Hamacher Operator. *Information Sciences*, 622, 374–404. https://doi.org/10.1016/j.ins.2022.11.143

Peng, X. & Huang, H. (2020). Fuzzy decision making method based on CoCoSo with CRITIC for financial risk evaluation. *Technological and Economic Development of Economy,* 26 (6),1199-1215. https://doi.org/10.3846/tede.2020.11920

Piasecki, M. & Kostyrko, K. (2020).Development of weighting scheme for indoor air quality model using a multiattribute decision making method. *Energies,* 13(12),3120. https://doi.org/10.3390/en13123120

Razzaq, A., Riaz, M. & Aslam, M. (2024). Efficient picture fuzzy soft CRITIC-CoCoSo framework for supplier selection under uncertainties in Industry 4.0. *AIMS Mathematics,* 9(1), 665-701. https://doi.org/10.3934/math.2024035

Shang, C., Saeidi, P. & Goh, C.F. (2022), "Evaluation of circular supply chains barriers in the era of industry 4.0 transition using an extended decision-making approach", *Journal of Enterprise Information Management,* Vol. 35 Nos 4/5, pp. 1100-1128.

Sharma,M., Joshi,S. & Govindan,K. (2023). Overcoming barriers to implement digital technologies to achieve sustainable production and consumption in the food sector: A circular economy perspective. *Sustainable Production And Consumption,* 39, 203-215. https://doi.org/10.1016/j.spc.2023.04.002

Sreekumar, V. & Rajmohan, M. (2019). Supply chain strategy decisions for sustainable development using an integrated multi-criteria decision making approach. *Sustainable Development,* 27:50–60. https://doi.org/10.1002/sd.1861

Torkayesh, A.E., Pamučar, D., Ecer, F. & Chatterjee, P. (2021a). An Integrated BWM-LBWA-CoCoSo Framework for Evaluation of Healthcare Sectors in Eastern Europe. *Socio-Economic Planning Sciences,* 78, 101052. https://doi.org/10.1016/j.seps.2021.101052

Torkayesh, A. E. & Torkayesh, S. E., (2021). Evaluation of information and communication technology development in G7 countries: An integrated MCDM approach. *Technology in Society*, 66, 101670. https://doi.org/10.1016/j.techsoc.2021.101670

Tuş, A., & Aytaç, A., E. (2019). The new combination with CRITIC and WASPAS methods for the time and attendance software selection problem. *OPSEARCH,* 56, 528–538. https://doi.org/10.1007/s12597-019-00371-6

Uluskan, M., Topuz, D. & Çimen, C. (2020). AHP, bulanık AHP, LBWA VE COPRAS yöntemleri ile tedarikçi değerlendirme: demiryolu sektöründe bir uygulama. *Eskişehir Osmangazi Üniversitesi Mühendislik ve Mimarlık Fakültesi Dergisi,* 30(3),412-430. https://doi.org/10.31796/ogummf.1068384

Wang, W., Chen, Y., Wang, Y., Deveci,M., Moslem, S. & Coffman, D. (2024). Unveiling the implementation barriers to the digital transformation in the energy sector using the Fermatean cubic fuzzy method. *Applied Energy,* 360,122756. https://doi.org/10.1016/j.apenergy.2024.122756

Wei, G., Lei, F., Lin, R., Wang, R., Wei, Y., Wu, J., & Wei, C. (2020). Algorithms for probabilistic uncertain linguistic multiple attribute group decision making based on the GRA and CRITIC method: application to location planning of electric vehicle charging stations. *Economic Research-Ekonomska Istraživanja*, 33(1), 828–846. https://doi.org/10.1080/1331677X.2020.1734851

Yazdani, M., Pamučar, D., Chatterjee, P. & Torkayesh, A.E. (2022). A Multi-Tier Sustainable Food Supplier Selection Model under Uncertainty. *Operations Management Research*, 15, 116–145. https://doi.org/10.1007/s12063-021-00186-z

Žižović, M. & Pamučar, D. (2019). New model for determining criteria weights: level-based weight assessment (LBWA) model. *Decision Making: Applications in Management and Engineering*, 2(2), 1-20. https://doi.org/10.31181/dmame1902102z

Zaher, H., Khalifa, H. A. & Mohamed, S. (2018). On Rough Interval Multi Criteria Decision Making. *International Journal of Scientific & Technology Research*, 7(3), 44-54. Corpus ID: 116022924

Zeng, S., Gao, L. & Wu, J. (2024). Data literacy evaluation of undergraduate in business majors based on probabilistic linguistic integrated EDAS method. *Granular Computing,* 9, 27. https://doi.org/10.1007/s41066-024-00453-x

Zhu, L., Lei,G. & Gao, J. (2023). Research on key influencing factors for site selection of DC microgrid-based hydrogen-electric hybrid refueling stations. *International Journal of Hydrogen Energy,* 48 (100), 39759-39779. https://doi.org/10.1016/j.ijhydene.2023.07.141