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Application of the FUCOM and MARCOS Methods for Selecting Logistics Service Providers

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Abstract: Selecting an optimal logistics service provider is a complex multi-criteria decision-making problem that directly affects a company's competitiveness. This paper proposes a hybrid MCDM model that integrates the Full Consistency Method (FUCOM) and Measurement Alternatives and Ranking according to Compromise Solution (MARCOS) methods. FUCOM was used to determine the weight coefficients of seven criteria, while MARCOS was applied to rank ten potential logistics providers in the market of Bosnia and Herzegovina. The case study was conducted for the company Hygiene Pro Team from Banja Luka. The results showed that provider P9 represents the most favorable solution, which was confirmed by an extensive sensitivity analysis that verified the stability of the model. The proposed FUCOM–MARCOS model provides a robust framework for strategic decision-making in logistics.

Keywords: Logistics provider; Outsourcing; FUCOM; MARCOS

1 Introduction

In modern business conditions, an increasing number of companies choose logistics outsourcing in order to focus on their core competencies. Selecting an optimal logistics provider is a complex multi-criteria decision-making problem that directly influences a company's competitiveness. Logistics services are no longer merely simple operational tasks; instead, logistics providers have become key strategic partners who connect production, distribution, and customers into an efficient system. Today's logistics providers perform far more than transportation and warehousing. In addition to offering standard services such as inventory management, customs brokerage, and freight forwarding, they also employ advanced technologies, including artificial intelligence, internet and blockchain. Their role goes well beyond cost reduction: they help companies improve efficiency, introduce innovations more easily, and expand globally. However, the success of outsourcing largely depends on how effectively the logistics provider is selected. Choosing the right provider is difficult because many factors, often conflicting, must be considered. Managers need to identify the best provider among numerous alternatives. The traditional selection approach, focused solely on the lowest price, is no longer sufficient and carries significant risks. This price-oriented perspective overlooks other important considerations that involve both quantitative criteria (service cost, capacity and flexibility, geographical coverage) and qualitative criteria (service quality, reliability, safety and insurance, scalability). The complexity of this problem requires the application of objective, transparent, and scientifically grounded methods. Multi-criteria decision-making (MCDM) offers a powerful analytical framework for addressing such strategic decision problems. In this paper, the focus is placed on the application of two relatively new and efficient

MCDM methods: Full Consistency Method (FUCOM) and Measurement Alternatives and Ranking according to Compromise Solution (MARCOS). In response to the identified challenges, this paper introduces an innovative hybrid approach that combines the advantages of the FUCOM method for determining consistent criterion weights with the ability of the MARCOS method to provide stable ranking of alternatives through compromise solutions. The main objective of this research is to develop and validate an integrated FUCOM–MARCOS MCDM model for the strategic evaluation and ranking of logistics service providers. The model is practically applied in a case study involving the assessment of ten potential logistics providers in the market of Bosnia and Herzegovina. FUCOM was used for the objective determination of criterion weights, while MARCOS was applied to produce the final ranking of logistics providers. The originality and contribution of this work lie in the application and integration of these methods to solve a specific logistics-related problem, thereby offering a stable and reliable decision-making framework compared to conventional approaches. The conclusions are supported by a conducted sensitivity analysis, which confirmed the stability and reliability of the obtained ranking. The paper is structured as follows: The second section provides a literature review on logistics outsourcing and the use of MCDM methods in selecting logistics providers. The third section describes in detail the theoretical foundations of the applied MCDM methods (FUCOM and MARCOS). The fourth section presents the case study and application of the integrated model. The fifth section offers a discussion, including sensitivity analysis and validation. Finally, the conclusion summarizes the research findings and suggests directions for future research.

2 Background

Selecting an optimal logistics provider is very important strategic decisions in modern supply chains. This decision directly affects overall operating costs, service quality, customer satisfaction, and the competitive advantage of a company in the market. Due to its complexity, which includes a wide range of quantitative and qualitative criteria, the selection of a logistics provider has been the subject of intensive research for decades in both academic and professional circles. Third-party logistics involves the engagement of external companies to perform logistics functions [1]. It is viewed as an integrated system for managing information, transportation, material handling, inventory, warehousing, and packaging, with Bowersox et al. [2] and Sweeney [3] emphasizing its evolution from an operational function to strategic coordination within supply chains. Kumar and Singh [4], Mitra [5], Singh et al. [6], and Angkiriwang et al. [7] highlight that the primary motive for outsourcing is the achievement of strategic advantages. These advantages include cost reduction, capital release, increased flexibility, and improved operational efficiency. According to Hassini et al. [8], a logistics service provider (LSP) is an external operator that manages, delivers, and controls key logistics activities, such as inventory management, transportation, and customs clearance, on behalf of the shipper. Rajesh et al. [9] point out that outsourcing leads to reductions in labor costs, inventory surpluses, warehousing and fleet requirements, as well as material losses, while Jung [10] and Sahu et al. [11] emphasize that a well-designed logistics provider selection process can significantly improve a company's business performance. Due to the complexity of the process, which includes a wide range of quantitative and qualitative criteria, the selection of a logistics provider has been addressed through the application of MCDM methods [12]. The foundations of multi-criteria decision-making under uncertainty were established by Chen and Hwang [13] through their work on fuzzy logic. The integration of fuzzy logic with MCDM techniques has become a key paradigm for modeling subjective judgments. The literature is dominated by classical and fuzzy hybrid models for logistics provider selection. Min and Percin [14] and Bianchini [15] apply the AHP approach to assess the consistency of expert opinions and determine criterion weights, while the TOPSIS technique is used for the final ranking of logistics providers. Nnanta and Chikwendu [16], as well as Nuengphasuk et al. [17], confirmed through empirical case studies the stability and reliability of the AHP–TOPSIS model, demonstrating its effectiveness as a dependable tool for selecting the optimal logistics provider. Ho et al. [18] developed an integrated approach combining QFD, fuzzy sets, and AHP, whereas Akman and Bayna [19] and Jovčić et al. [20] successfully applied an integrated fuzzy-based approach for evaluating and selecting logistics service providers. The proposed methodology combines fuzzy AHP for determining criterion weights with fuzzy TOPSIS for ranking alternatives, aiming to overcome uncertainty and subjectivity in decision-makers' assessments. A new wave of research after 2015 is characterized by the development of more sophisticated hybrid models and the introduction of new MCDM methods aimed at achieving greater stability in decision-making related to logistics provider selection. Falsini et al. [21] propose a model that integrates AHP, DEA, and linear programming. The validation of the proposed model was carried out through a real case study of an international logistics provider. Wang et al. [22] developed a hybrid MCDM model for the evaluation and selection of suppliers in the oil and gas industry. The model integrates SCOR metrics, the AHP method, and the TOPSIS technique, enabling a comprehensive analysis of both quantitative and qualitative criteria. Pamučar et al. [23] developed and applied an integrated approach using Interval Rough Numbers (IRN) with the IRN-BWM, IRN-WASPAS, and IRN-MABAC methods. Sremac et al. [24] applied Rough SWARA and Rough WASPAS for evaluating providers of hazardous materials transport services, demonstrating the stability of the model, while Sinani et al. [25] developed the Rough Dombi–Hamy Mean (RNDHM) operator designed for solving the complex problem of third-party logistics provider selection. A new methodological approach for ranking and weighting in the selection of transport service providers was introduced by Pamučar and Ljubojević [26] through the development of the Fuzzy–Real Ideal Comparative (F-R1C) model. This two-phase fuzzy model integrates the DEMATEL method for analyzing interrelationships among criteria and determining their ideal weighted values. In the second phase, the model introduces a comparative analysis between the obtained ideal values and the perceived actual values of provider criteria, enabling their evaluation and ranking. Additionally, Pamučar et al. [27] developed the FUCOM method, which demonstrates better consistency than the BWM and AHP methods. Stević et al. [28] developed the MARCOS method for compromise ranking of alternatives. The developed method was compared with six other MCDM methods for verification purposes. The results showed that the method is applicable and capable of simulating various scenarios. Servaitė et al. [29] examined the use of the VIKOR and TOPSIS methods for evaluating and selecting logistics providers, while Stević et al. [30] developed an integrated model combining DEA, PCA, CRITIC, Entropy, and MARCOS methods to determine the efficiency of transportation companies. Jovčić and Pruša [31] proposed a hybrid model for evaluating and selecting logistics providers using the Entropy, CRITIC, and ARAS methods. Their approach eliminates subjectivity and provides stable solutions, which was confirmed through sensitivity analysis. Contemporary research increasingly focuses on sustainability and emerging technologies. Mavi et al. [32] developed a model for evaluating sustainable reverse logistics service providers that simultaneously considers sustainability and risk criteria. Fuzzy SWARA was used to determine criterion weights, while fuzzy MOORA was applied for ranking the providers. Xie et al. [33] designed a framework for green supplier selection (GSS) by integrating Industry 4.0 and circular economy principles with Pythagorean fuzzy numbers, SWARA, and COPRAS methods. Sahoo et al. [34] emphasize the transformative impact of Industry 4.0 on supplier selection criteria. A systematic literature review, including works by Akhtar [35] and Andrejić and Pajić [36], confirms the dominance of operational and financial criteria and the widespread use of MCDM methods, particularly AHP and TOPSIS. Although extensive literature exists on the application of MCDM methods in logistics provider selection, a methodological gap has been identified regarding the use of FUCOM and MARCOS methods. The absence of studies that directly combine these methods in the context of logistics provider selection creates a research gap. Specifically, there is a lack of research that integrates these two methods for the selection of logistics providers in the market of Bosnia and Herzegovina.

3 Methods

Taking into account the complexity of the problem and its sensitivity to changes in weight coefficients and the large number of criteria involved in selecting a logistics provider, this study employs the FUCOM and MARCOS methods to objectively and transparently identify the best logistics service provider.

3.1 Full Consistency Method (FUCOM)

The FUCOM method [27] has been used for calculation of criteria weights. This method can be described through following steps:

Step 1: Sorting criteria according to their expected importance.

$$C_{i(1)} > C_{i(2)} > \cdots > C_{i(k)} \tag{1}$$

Step 2: The ranked criteria need to be compared and comparative priority should be calculated ($\varphi_{k/(k+1)}, k = 1, 2, \ldots, n$), where "$k$" represents the ranking of the criteria:

$$\Phi = \left(\varphi_{1/2}, \varphi_{2/3}, \ldots, \varphi_{k/(k+1)}\right) \tag{2}$$

Step 3: The final criteria weights ($(w_1, w_2, \ldots, w_n)^{\mathrm{T}}$) are calculated using the Eq. (3):

$$\begin{aligned}
&\min \chi \\
&\text{s.t.:} \\
&\left[\frac{w_{j(k)}}{w_{j(k+1)}} - \varphi_{k/(k+1)}\right] = \chi, \forall j \\
&\left[\frac{w_{j(k)}}{w_{j(k+1)}} - \varphi_{k/(k+1)} \otimes \varphi_{(k+1)/(k+2)}\right] = \chi, \forall j \\
&\sum_{j=1}^{n} w_j = 1 \\
&w_j \geq 0, \forall j
\end{aligned} \tag{3}$$

3.2 Measurement Alternatives and Ranking According to Compromise Solution (MARCOS) Method

The MARCOS method is described through the following steps [28]:

Step 1: Initial decision-making matrix.

Step 2: Formation of an extended initial matrix with defining the ideal (AI) and anti-ideal (AAI) solution. The AAI is the worst alternative, while the AI is the best alternative. In accordance to nature of the criteria, AAI and AI are defined:

$$AAI = \min_{j} x_{ij} \text{ if } j \in B \quad \text{and} \quad \max_{j} x_{ij} \text{ if } j \in C \tag{4}$$

$$AAI = \max_{j} x_{ij} \text{ if } j \in B \quad \text{and} \quad \min_{j} x_{ij} \quad \text{if } j \in C \tag{5}$$

where, B marks a benefit group of criteria, while C denotes a group of cost criteria.

Step 3: Process of normalization.

$$A\,n_{ij} = \frac{x_{ai}}{x_{ij}} \text{ if } j \in C \tag{6}$$

$$n_{ij} = \frac{x_{ij}}{x_{ai}} \text{ if } j \in B \tag{7}$$

where, x_{ij} and x_{aj} denotes the elements of the initial matrix.

Step 4: Computation of the weighted matrix $= [V_{ij}]\, m \times n$.

$$V_{ij} = n_{ij} \times w_j \tag{8}$$

Step 5: Computation of the utility degree of alternatives K_i.

$$K_i^- = \frac{s_i}{s_{aai}} \tag{9}$$

$$K_i^+ = \frac{s_i}{s_{ai}} \tag{10}$$

where, $\mathrm{S_i}(i = 1, 2, \ldots, m)$ represents the sum of the matrix V :

$$S_i = \sum_{i=1}^{n} V_{ij} \tag{11}$$

Step 6: Determination of the utility function of alternatives $f(Ki)$.

$$f\left(K_i\right) = \frac{K_i^+ + K_i^-}{1 + \frac{1 - f\left(K_i^+\right)}{f\left(K_i^+\right)} + \frac{1 - f\left(K_i^-\right)}{f\left(K_i^-\right)}} \tag{12}$$

where, $f\left(K_i^-\right)$represents the utility function in relation to the AAI solution, while $f\left(K_i^+\right)$represents the utility function in relation to the AI solution.

$$f\left(K_i^-\right) = \frac{K_i^+}{K_i^+ + K_i^-} \tag{13}$$

$$f\left(K_i^+\right) = \frac{K_i^-}{K_i^+ + K_i^-} \tag{14}$$

Step 7: Ranking the alternatives.

4 Case Study and Results

The case study was conducted for the newly established company "Hygiene Pro Team" from Banja Luka, whose primary business activity is the distribution of hygiene products, professional equipment, and cleaning chemicals. The company currently leases warehouse space but does not own its own vehicle fleet; for this reason, it is open to collaboration with logistics providers for the import of goods from abroad as well as for domestic distribution within Bosnia and Herzegovina. Consequently, selecting the right provider is crucial to ensure reliable and efficient logistics support. To identify suitable partners for logistics services, a comprehensive preliminary analysis of the logistics provider market in Bosnia and Herzegovina was conducted. As a result of the research, a total of ten potential candidates (P1 to P10) were identified, forming the initial set for further, more detailed evaluation. The analysis of logistics providers was based on publicly available information, including corporate presentations, media references, and market reputation. The providers represent a heterogeneous group, including both domestic providers with significant local experience and subsidiaries of international logistics providers with a global network and standardized procedures. To ensure reliable and directly comparable data, a survey was conducted with all ten identified logistics providers. The survey was structured and specifically designed for the purposes of this study, aiming to collect quantitative data on key operational and financial parameters. The primary goal of the survey was to obtain standardized data that would enable an objective comparative analysis.

4.1 Definition of Criteria and Determination of Weights

To make an appropriate and strategic decision regarding the selection of a logistics provider for Hygiene Pro Team, a comprehensive set of seven criteria was defined. The established set of criteria consists of a combination of quantitative and qualitative measures, determined through a review of relevant academic literature and interviews with the company's management. The aim was to ensure that the criteria are not merely generic but accurately reflect the specific operational and strategic needs of Hygiene Pro Team. The first criterion (C1) relates to the service price, expressed in Convertible Marks (BAM), which is to be minimized. The value is determined for a standardized service package covering the import of one 40-foot container, customs and forwarding services, and the distribution of one pallet of goods to a destination in Banja Luka. The second criterion (C2) is capacity, expressed as the number of available vehicles, which is to be maximized, as higher capacity indicates greater operational capability. The third criterion (C3) is geographical coverage, expressed as the number of countries in which the provider operates. This quantitative criterion should also be maximized, as broader geographical reach directly impacts the company's operations. The fourth, fifth, sixth, and seventh criteria are qualitative and should be maximized. They are evaluated using a modified Likert scale ranging from 1 (Very Poor) to 7 (Excellent). The final score for each provider represents the arithmetic mean of the evaluations of all decision-makers, which allows for a transparent assessment of subjective aspects. The fourth criterion (C4) refers to the reliability and reputation of the provider. This criterion primarily concerns the provider's ability to consistently fulfill obligations on time, which is critical for maintaining uninterrupted supply chains. The fifth criterion (C5) is service quality, encompassing all aspects of the customer experience, from the professionalism and responsiveness of personnel to the transparency and quality of information systems for tracking. The sixth criterion (C6) is safety and insurance, which includes both physical and information safety, as well as adequate financial protection through insurance policies. The seventh criterion (C7) is scalability, meaning the provider's organizational and operational capacity to support the dynamic growth and changing demands of Hygiene Pro Team, including flexibility in adapting to varying business volumes and complexity. Using the FUCOM method, decision-makers first ranked the defined criteria and then determined their comparative significance. Based on the input data, objective weighting coefficients were calculated for each criterion (Table 1). These weighting coefficients indicate which criteria are of the greatest strategic importance for Hygiene Pro Team in the outsourcing process.

Table 1. Values of weighting coefficients

		DO1	**DO2**	**DO3**	**DO4**	**DO5**	W_j
C1	Service price	0.237	0.286	0.200	0.222	0.196	**0.228**
C2	Capacity and flexibility	0.081	0.095	0.075	0.089	0.073	**0.083**
C3	Geographical coverage	0.081	0.071	0.086	0.076	0.084	**0.080**
C4	Reliability and reputation	0.189	0.190	0.200	0.266	0.196	**0.208**
C5	Service quality	0.284	0.190	0.299	0.222	0.294	**0.258**
C6	Safety and insurance	0.071	0.095	0.075	0.067	0.084	**0.078**
C7	Scalability	0.057	0.071	0.067	0.059	0.073	**0.065**
						SUM	**1**

A comparative analysis using the FUCOM method showed that, when comparing the five criteria, the highest weight for decision-makers is attributed to service quality, with a weight of 0.258, followed by service price with a weight of 0.228. Next are the criteria reliability and reputation with a weight of 0.208, capacity and flexibility with a weight of 0.083, geographical coverage with a weight of 0.080, safety and insurance with a weight of 0.078, and finally scalability, which has the lowest weight of 0.065.

4.2 Evaluation and Selection of a Logistics Provider Using the MARCOS Method

After determining the weights of the criteria affecting the selection of a logistics provider, the process of selecting the optimal logistics provider was carried out using the MARCOS method. Three decision-makers were surveyed, who performed evaluations using a Likert scale, and the calculation was based on their average values. The evaluations were conducted according to the code names of the logistics providers to ensure anonymity and objectivity in the selection process. Table 2 presents the extended initial decision matrix in accordance with the second step of the MARCOS method, i.e., Eqs. (4) and (5).

Table 2. Extended initial decision matrix

	C1	C2	C3	C4	C5	C6	C7
AAI	11442	30	12	4	4	5	3
P1	9020	45	20	5	4	5	3
P2	9594	270	50	5	6	5	6
P3	9532	30	15	4	4	5	3
P4	9210	35	15	5	4	5	3
P5	10317	150	20	5	6	5	5
P6	9435	195	40	5	4	5	4
P7	9815	220	19	5	5	6	5
P8	11442	2000	100	7	7	6	7
P9	11142	4000	130	7	7	7	7
P10	10128	180	12	6	5	5	4
AI	9020	4000	130	7	7	7	7
max/min	min	max	max	max	max	max	max

The next step in the MARCOS method is calculating the normalization of the extended initial matrix. Normalization is performed using Eqs. (6) and (7) and is presented in Table 3. An example of the normalization calculation, shown in Table 4, is as follows:

For provider P1 when the criterion is min : $n_{ij} = \frac{x_{ai}}{x_{ij}}$ if $j \in C \Rightarrow n_{11} = \frac{9020}{9020} = 1.000$

For provider P2 when the criterion is max: $n_{ij} = \frac{x_{ij}}{x_{ai}}$ if $j \in B \Rightarrow n_{12} = \frac{45}{4000} = 0.011$

Table 3. Normalized decision matrix

	C1	C2	C3	C4	C5	C6	C7
AAI	0.788	0.008	0.092	0.571	0.571	0.714	0.429
P1	1.000	0.011	0.154	0.714	0.571	0.714	0.429
P2	0.940	0.068	0.385	0.714	0.857	0.714	0.857
P3	0.946	0.008	0.115	0.571	0.571	0.714	0.429
P4	0.979	0.009	0.115	0.714	0.571	0.714	0.429
P5	0.874	0.038	0.154	0.714	0.857	0.714	0.714
P6	0.956	0.049	0.308	0.714	0.571	0.714	0.571
P7	0.919	0.055	0.146	0.714	0.714	0.857	0.714
P8	0.788	0.500	0.769	1.000	1.000	0.857	1.000
P9	0.810	1.000	1.000	1.000	1.000	1.000	1.000
P10	0.891	0.045	0.092	0.857	0.714	0.714	0.571
AI	1.000	1.000	1.000	1.000	1.000	1.000	1.000

The next step in the MARCOS method is the calculation of the weighted normalized matrix. This calculation is performed by multiplying the previously calculated normalized matrix by the criterion weight coefficients w_j which were determined earlier using the FUCOM method (w_1 = 0.228,w_2 = 0.083, w_3 = 0.080, w_4 = 0.208, w_5 = 0.258, w_6 = 0.078, w_7 = 0.065). The weighted matrix is presented in Table 4. An example of the weighted matrix calculation is as follows: $V_{ij} = n_{ij} \times w_j = 0.788 \times 0.228 = 0.180$ (Eq. (8)).

By applying Eq. (11), all values were summed (row-wise) for the alternatives as follows:

Table 4. Weighted normalized decision matrix

	C1	C2	C3	C4	C5	C6	C7
AAI	0.180	0.001	0.007	0.119	0.147	0.056	0.028
P1	0.228	0.001	0.012	0.149	0.147	0.056	0.028
P2	0.214	0.006	0.031	0.149	0.221	0.056	0.056
P3	0.216	0.001	0.009	0.119	0.147	0.056	0.028
P4	0.223	0.001	0.009	0.149	0.147	0.056	0.028
P5	0.199	0.003	0.012	0.149	0.221	0.056	0.046
P6	0.218	0.004	0.025	0.149	0.147	0.056	0.037
P7	0.210	0.005	0.012	0.149	0.184	0.067	0.046
P8	0.180	0.042	0.062	0.208	0.258	0.067	0.065
P9	0.185	0.083	0.080	0.208	0.258	0.078	0.065
P10	0.203	0.004	0.007	0.178	0.184	0.056	0.037
AI	0.228	0.083	0.080	0.208	0.258	0.078	0.065

$S_{AAI} = 0.180 + 0.001 + 0.007 + 0.119 + 0.147 + 0.056 + 0.028 = 0.538$. The remaining values were obtained in a similar manner. After that, by applying Eq. (9), the utility degrees relative to the anti-ideal solution were calculated: $K_1^- = \frac{Si}{Saai} = \frac{0.621}{0.538} = 1.155$ while the utility degrees relative to the ideal solution are calculated using Eq. (10), e.g.: $K_1^+ = \frac{Si}{Sai} = \frac{0.621}{1} = 0.621$. After calculating the utility degrees with respect to the anti-ideal and ideal solutions, the next step is to compute the utility function relative to the anti-ideal solution using Eq. (13). An example is: $f\left(K_1^-\right) = \frac{K_1^+}{K_1^+ + K_1^-} = \frac{0.621}{0.621+1.155} = 0.350$. The utility function relative to the ideal solution is obtained using Eq. (14), e.g.: $f\left(K_1^+\right) = \frac{K_1^-}{K_1^+ + K_1^-} = \frac{1.155}{0.621+1.155} = 0.650$. Finally, the overall utility function for provider P1 is obtained by applying Eq. (12): $f(K_1) = \frac{K_1^+ + K_1^-}{1 + \frac{1-f\left(K_1^+\right)}{f\left(K_1^+\right)} + \frac{1-f\left(K_1^-\right)}{f\left(K_1^-\right)}} = \frac{0.621+1.155}{1+\frac{1-0.650}{0.650}+\frac{1-0.350}{0.350}} = 0.5226$. The remaining values were calculated in an identical manner, with the final results presented in Table 5.

Table 5. Results of MARCOS method

	S_i	K_i^-	K_i^+	$f\left(K_i^-\right)$	$f\left(K_i^+\right)$	$f(K_1)$	RANG
AAI	0.538	1					
P1	0.621	1.155	0.621	0.350	0.650	0.5226	8
P2	0.732	1.361	0.732	0.350	0.650	0.6161	3
P3	0.575	1.070	0.575	0.350	0.650	0.4844	10
P4	0.613	1.140	0.613	0.350	0.650	0.5159	9
P5	0.687	1.277	0.687	0.350	0.650	0.5780	4
P6	0.635	1.182	0.635	0.350	0.650	0.5349	7
P7	0.672	1.250	0.672	0.350	0.650	0.5656	5
P8	0.881	1.638	0.881	0.350	0.650	0.7413	2
P9	0.957	1.779	0.957	0.350	0.650	0.8052	1
P10	0.670	1.246	0.670	0.350	0.650	0.5637	6
AI	1.000	1.860	1.000				

Table 5 clearly shows that, according to the defined criteria and the MARCOS methodology, the best choices for logistics services are providers P9 and P2. On the other hand, providers P3, P4, and P1 were found to be the least favorable choices based on the given evaluation parameters.

5 Sensitivity Analysis and Discussion

In this paper, an extensive sensitivity analysis was carried out to determine how variations in the initial weighting coefficients of the criteria affect the final ranking of logistics providers obtained using the MARCOS method. The modification of the weighting coefficients was performed by multiplying the obtained criterion weights (C1 = 0.228, C2 = 0.083, C3 = 0.080, C4 = 0.208, C5 = 0.258, C6 = 0.078, and C7 = 0.065) by values of 0.95%, 0.85%, 0.75%, 0.65%, 0.55%, 0.45%, 0.35%, 0.25%, 0.15%, and 0.05%. In fact, all values are multiplied by the weighting coefficient C1 (service price) (0.228*0.95, 0.228*0.85, 0.228*0.75, etc., up to 0.228*0.05) and the same procedure is applied analogously to the weighting coefficients C2 (capacity and flexibility), C3 (geographical coverage), C4 (reliability and reputation), C5 (service quality), C6 (safety and insurance), and C7 (scalability). In this way, new weighting coefficients are obtained and grouped from S1 to S70. The analysis was conducted through 70 different scenarios involving the modification of weighting coefficients in the MARCOS method. After the calculations were performed, changes in the ranking of all logistics providers (alternatives) were obtained depending on the changes in criterion weights. Figure 1 presents a comparative overview of the MARCOS ranking with the applied changes in the weighting coefficient values.

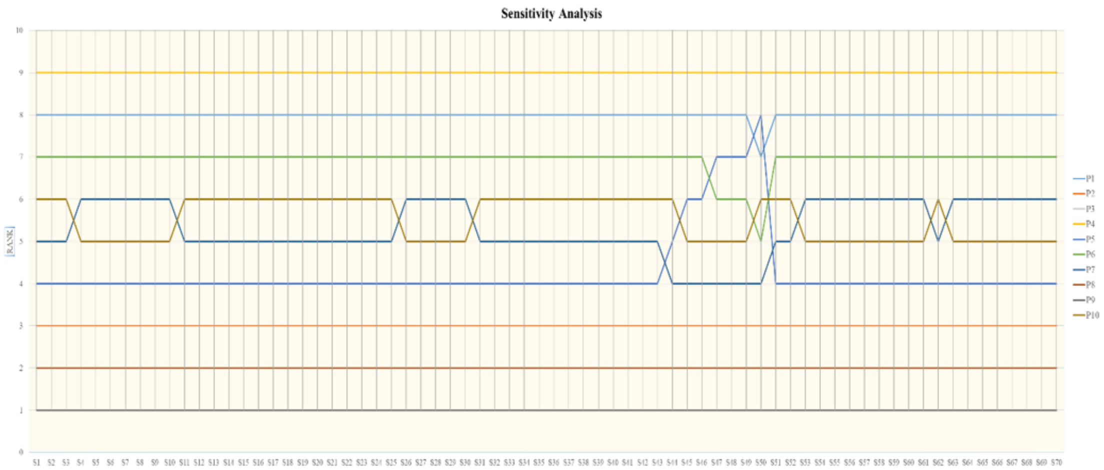

Figure 1. Comparative overview of the ranking of alternatives using the MARCOS method with modified criteria weights

Figure 1 illustrates the changes in the ranking of ten logistics providers, from P1 to P10, across 70 different scenarios involving modifications of the criteria weighting coefficients. Based on the presented results, it can be observed that certain providers maintain a stable rank throughout most scenarios, indicating the reliability of the MARCOS model. Notably, providers P9, P8, and P2 consistently stand out, with P9 always ranked first, P8 second, and P2 third. Their rankings show minimal fluctuations, remaining firmly positioned at the first, second, and third places. This suggests that they are not dependent on variations in criteria weights and that they represent the most reliable providers in the selection process. Conversely, providers P1, P5, P6, P7, and P10 exhibit variations in their rankings, indicating their sensitivity to specific criteria and that their competitiveness depends on particular weighting values. Providers P3 and P4 occupy the lowest ranks throughout the entire set of scenarios, with their positions remaining unchanged, confirming their consistently weaker competitiveness compared to the other providers. Although the proposed FUCOM-MARCOS model demonstrated stable results, this study has certain limitations. First, the evaluation of qualitative criteria (C4–C7) is based on subjective assessments from five decision-makers, which introduces a degree of bias. Second, although the sensitivity analysis is extensive, applying the model to a larger number of providers or in different industrial contexts could yield different results. Third, the model does not explicitly incorporate dynamic aspects, such as long-term trends in provider performance. These limitations also represent directions for future research.

6 Conclusions

In today's business environment, characterized by globalization, rapid market changes, and strong competition, outsourcing logistics has become crucial for efficient operations and long-term competitive advantage. This study applied the MCDM methodology to the problem of selecting the most suitable logistics provider for the company "Hygiene Pro Team". A comprehensive procedure was conducted, encompassing theoretical preparation, criteria definition, alternative evaluation, and result validation. Based on a literature review and interviews with the management of "Hygiene Pro Team", a set of seven decision-making criteria was established: service price, capacity and flexibility, geographical coverage, reliability and reputation, service quality, safety and insurance, and scalability. Using the FUCOM method, the weighting values of these criteria were determined, with service quality (0.258), price (0.228), and reliability (0.208) emerging as the most significant. This indicates that cost efficiency and operational efficiency are of critical importance for the analyzed company. The evaluation of ten previously identified logistics providers using the MARCOS method clearly highlighted provider P9 (with a utility function value of 0.8052) as the most favorable option. This provider demonstrated the best performance relative to both the ideal and anti-ideal solutions, confirming its superiority with respect to the established criteria. The stability of this choice was further validated through sensitivity analysis, which showed that provider P9 retains the first position even when the weighting coefficients vary, thereby confirming the robustness and reliability of the initial ranking. The integrated FUCOM-

MARCOS approach presented in this study has proven to be an effective tool for reducing subjectivity in complex strategic decision-making. It enables decision-makers to systematically balance numerous, often conflicting, criteria, ensuring a rational and transparent selection process based on explicit data. Although the proposed methodology was successfully applied, the study opens several directions for future research: (1) Identifying additional criteria that may influence a redefinition of the evaluation model used in this work; (2) Integration with soft computing techniques and artificial intelligence; (3) Expanding the application to other sectors and larger samples of providers. Implementing these research directions would significantly enhance both the scientific foundation and the practical applicability of the logistics provider selection process, contributing to more efficient and responsible supply chain management.

Data Availability

The data used to support the research findings are available from the corresponding author upon request.

Conflicts of Interest

The authors declare no conflict of interest.

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