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Küresel Bulanık TOPSIS Yöntemi ile 3. Part Tersine Lojistik Hizmet Sağlayıcı Seçimi

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Öz: Çevresel nedenlerle ihtiyaç duyulan ve işletmeler tarafından rekabet avantajı olarak görülen kullanılmış malların geri dönüştürülmesi sonucunda tersine lojistiğin önemi her geçen gün artmaktadır. Tersine lojistik sistemlerinde yapılan değişiklikler sonucunda işletmelerin karlılıkları artmakta ve tüketiciler nezdindeki imajları iyileşmektedir. Tersine lojistik hizmetleri genellikle işletmeler tarafından 3PRLP'ye dış kaynaklı olarak verilir. Bir firma için uygun olmayan bir 3PRLP seçmek, kaynak verimliliğini azaltacak, operasyonel tehlikeleri artıracak ve şirketin uzun vadeli büyümesine potansiyel olarak zarar verecektir. Sonuç olarak, uygun 3PRLP değerlendirmesi ve seçimi, çeşitli kriterler, grup karar verme ve çeşitli belirsizlik seviyeleri gerektirebilir. Bu nedenle, bu çalışmada tersine lojistik faaliyeti gösteren işletmelerin belirsizliği dikkate alan ve 3PRLP seçiminde ve değerlendirmesinde yardımcı olabilecek SFS dayalı TOPSIS modeli önerilmiştir. Önerilen model Alüminyum sektöründeki bir işletme için uygulanmış ve sonuçları paylaşılmıştır.

Third Part Reverse Logistics Service Provider Selection Using the Spherical Fuzzy TOPSIS Method

Keywords
Spherical Fuzzy TOPSIS 1,
Third Part Reverse Logistics Service Provider 2,
MCDM 3

Abstract: The relevance of reverse logistics is increasing day by day as a result of the recycling of used goods, which is required for environmental reasons and seen as a competitive advantage by enterprises. The profitability of enterprises increases and their image in the eyes of consumers improves as a result of changes achieved in reverse logistics systems. Reverse logistics services are typically outsourced to 3PRLP by businesses. Choosing an inappropriate 3PRLP for a firm will diminish resource efficiency, increase operational hazards, and potentially harm the company's long-term growth. As a result, the SFS-based TOPSIS model has been suggested in this study, which takes uncertainty into consideration and can aid in the selection and evaluation of 3PRLP. The proposed model is applied on a company in the aluminum industry, and the findings are presented.

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1. Introduction

Reverse Logistics (RL) is the process of planning, implementing, and controlling the efficient, cost-effective flow of raw materials, in-process inventory, finished items, and related data from the point of consumption to the point of origin [1]. The backward movement of materials from the customer to the supplier is known as logistics, and it aims to maximize the value generated from the returned product while lowering the total cost of RL [2]. While RL efforts help businesses save money, they also boost their reputation. RL is a method for businesses to become more ecologically friendly. Many firms throughout the world have recognized the value of RL in terms of both cost and environmental impact, and have implemented it into their business missions. A strong RL technique gives a company a competitive advantage by lowering the cost of raw materials and material acquisition, lowering the customer's purchasing risk, shortening response time, satisfying social duty, and increasing the company's image as a "green" company [3]. RL is becoming increasingly important as a result of these developments. As a result, some organizations that require an efficient RL network build their own, while others outsource their RL activities. As a result of this situationt, third-party logistics companies that specialize in RL are becoming more important [4].

For enterprises to effectively adopt RL, an appropriate RL network for reverse processes such as collection, separation, inspection, storage, disassembly, compaction, and delivery must be established. RL can be done using an existing network or through specialized RL companies. Many organizations, even successful forward logistics operators, are unable to handle the reverse flow properly and effectively. The majority of logistics systems are unprepared to handle product movement in the reverse channel [5]. RL system operations and management is a difficult process that necessitates a lot of infrastructure, technology, expertise, and experience [6]. Many businesses opt to outsource their logistics to specialist third-party logistics service providers in order to gain a competitive advantage, cut expenses, and increase the quality of second-hand product recovery [7]. As a result, it's critical for businesses to choose the best third-party reverse logistics provider (3PRLP) based on the desired selection criteria [8]. This condition poses a difficult area in terms of how businesses will select and evaluate 3PRLP [4]. The 3PRLP selection procedure is frequently carried out in a complicated and unpredictable environment, making it difficult for decision-makers to make definite decisions. When developing a decision model, all of these factors should be taken into account [1]. This study's goal is to develop a selection and assessment model that can aid in the selection and evaluation of organizations that operate in RL while taking uncertainty into consideration, as well as to deploy an application. As a result, for the selection and evaluation of 3PRLP, the TOPSIS method based on Spherical Fuzzy (SF) clusters is proposed in the study, which takes into account a wider preference area and degree of indecision that companies can easily use in their daily work, and the proposed method is applied to the Aluminum industry. New fuzzy sets, known as spherical fuzzy sets (SFS), give DM more options, and they can describe the degree of indecision about an alternative based on a criterion, regardless of membership or non-membership degrees. The theoretical foundation of SFS is built on Pythagorean fuzzy sets' wider field approach and the premise that neutrosophic sets define instability independently. SFS combine these two approaches in a single theory [9]. SFS allow experts to assign more degrees of membership, non-membership, and hesitation. SFS outperform Pythagorean, intuitionistic fuzzy, and neutrophic sets in this regard. Because of the fuzziness, judgments are stated more fully in SFS. Degrees of non-membership and hesitation are used to define membership in fuzzy sets. The degree of hesitation is assigned independently of the other two parameters in SFS theory [10]. In the selection of 3PRLP, SFS have not yet been used. This article is unique in that it is the first to use SFS in the 3PRLP selection.

The TOPSIS method based on SFS will be used to give a solution to the 3PRLP selection problem that takes into account more than one expert, multiple criteria, and alternatives. This research aids aluminum manufacturers in the evaluation and selection of 3PRLP partners, while also improving RL efficiency and effectiveness. The research will contribute to the literature in this subject by helping to develop the 3PRLP evaluation criteria, prioritizing and selecting the best alternative among the options in the SFS.

The following is how the rest of the article is structured. In Chapter 2, a review of the literature on 3PRLP is provided. The proposed approach and SFS are discussed in Chapter 3. The application for the Aluminum sector is presented in Chapter 4. Chapter 5 contains the debate and conclusion.

2. Literature Review

The 3PRLP selection is considered a multi-criteria decision-making problem due to the existence of many relevant criteria. When we look at the literature, we discover that many multi-criteria decision-making procedures are utilized to choose 3PRLP. A summary of these studies may be seen below.

Meade and Sarkis [11] used the ANP method to select 3PRLP based on product life cycle stages, organizational performance, RL process functions, and the organization's role in reverse logistics. For 3PRLP selection, Efendigil et al. [12] suggested a two-stage model based on artificial neural networks and fuzzy AHP. On-time delivery rate, approved occupancy rate, service quality level, unit operating cost, capacity utilization rate, total order cycle time, system flexibility index, level index, rise in market share, and R&D ratio are among the criteria are utilized in their research. Kannan et al. [2] used the ISM (Interpretive Structural Model) and fuzzy TOPSIS methods to select 3PRLP for the battery recycling industry, based on the criteria of quality, delivery,inability to meet future requirements, willingness, attitude, RL cost, rejection rate. For 3PRLP selection, Saen [13] employed data envelopment analysis with factors including total cost of shipments, reputation of 3PRLP, and number of flawless invoices received from 3PRLP provider. Cheng and Lee [14] used the ANP (Analytical Network Process) method to select 3PRLP for advanced technology manufacturing companies, based on warehouse management, transportation management, information technology management, and value-added services criteria. Using the ANP technique, Govindan et al. [15] chose 3PRLP based on qualifications, operational performance, organizational role, technical advancements, risk management, financial performance, user satisfaction, geographical dispersion, and network size. Senthil et al. [16] used the AHP and TOPSIS method in a fuzzy environment to select 3PRLP for a plastics recycling factory based on organizational performance criteria, RL process functions, organizational role of reverse logistics, resource capacity, corporate alliance, location experience, and communication systems. For business performance, resource capacity, delivery service RL operations, communication and information technology system, geographic location, and experience criteria, Prakash and Barua [17] presented a combined model for 3PRLP selection utilizing Fuzzy AHP and VIKOR techniques. Zarbakhshnia et al. [6] suggested a combined model for 3PRLP selection based on economic, environmental, social, and risk criteria, using fuzzy SWARA-fuzzy COPRAS methodologies. Bai and Sarkis [5] proposed the rough set-based TOPSIS and VIKOR method for 3PRLP selection using cost, time, quality, flexibility, innovation criteria. Pamucar et al.[18] developed a novel technique for 3PRLP selection employing service, logistics cost information system, intangible, and geolocation criteria, which includes BWM-WASPAS-MABAC methods. By merging the Combined Compromise Solution (CoCoSo) and CRITIC methodologies with Single Value Neutrophic Clusters (SVNSs) and employing economic, environmental, social, and risk criteria, Mishra et al. [19] developed a new integrated methodology to selection 3PRLP. Using the criteria of basic capabilities, RL activities, RL functions, technology and communication competences, environmental factors, quality, cost, and experience, Arsu and Aycin [20] proposed the fuzzy SWARA technique for 3PRLP selection.

When looking at research that employed the SF- TOPSIS method, Kocakaya et al. [21] used the SF-AHP-TOPSIS method for Regional Aircraft Type Selection in Turkey. Mathew et al. [22] used the the SF- AHP-TOPSIS approach for the production system selection problem. Gündoğdu and Kahraman [23] used the SF-TOPSIS approach for the ideal placement selection of the electric car charging station. Jaller and Otay [24] evaluated sustainable vehicle solutions for freight transport using the SF-AHP -TOPSIS technique. Onar et al. [25] used the SF-TOPSIS method for selection of learning analytics methods. For the Automated Storage and Retrieval Systems technology selection problem, Bolturk [26] used the SF- TOPSIS technique.

When we look at the literature, we see multi-criteria decision-making strategies for 3PRLP selection that incorporate typical fuzzy sets. In the selection of 3PRLP, there are multiple DM, and DM often have insufficient information and cannot master all criteria's aspects. DM make decisions in an environment that is both complex and uncertain [27]. In uncertain situations, SFS are effective decision-making tools. Because of the uncertainty, DM judgments are expressed more comprehensively in SFS. In this study, the TOPSIS method combined with the SFS is proposed for 3PRLP selection. The proposed methods are intended to contribute to the literature on 3PRLP selection by dealing with uncertainty more effectively and to assist managers in making decisions.

3. Material and Method

3.1. Spherical Fuzzy Sets

Kutlu Gündoğdu and Kahraman introduced SFS as an extension of IFS. The idea behind SFS is to let DM to generalize other extensions of fuzzy sets by defining a membership function on a spherical surface and independently assign the parameters of that membership function with a larger domain. A SFS must satisfy the following condition [9,27]:

$$0 \leq \mu_A^2(u) + \mu_A^2(u) + \mu_A^2(u) \leq 1 \quad \forall_u \in U$$

3.1.1. Operations on the Spherical Fuzzy Sets

Addition: The operation of adding two SFS X_S and Y_S is stated as follows.

$$X_S \oplus Y_S = \left\{ ({\mu_{X_S}}^2 + {\mu_{Y_S}}^2 - {\mu_{X_S}}^2 . {\mu_{Y_S}}^2)^{1/2}, \vartheta_{X_S}\vartheta_{Y_S}, ((1 - {\mu_{Y_S}}^2){\pi_{X_S}}^2 + (1 - {\mu_{X_S}}^2){\pi_{Y_S}}^2 - {\pi_{X_S}}^2 . {\pi_{Y_S}}^2)^{1/2} \right\} \quad (1)$$

Product: The following is an expression for multiplying two SFS, X_S and Y_S .In decision-making method applications, this step is critical for constructing weighted decision matrices.

$$X_S \oplus Y_S = \left\{ \mu_{X_S}\mu_{Y_S}, ({\vartheta_{X_S}}^2 + {\vartheta_{Y_S}}^2 - {\vartheta_{X_S}}^2 . {\vartheta_{Y_S}}^2)^{1/2}, ((1 - {\vartheta_{Y_S}}^2){\pi_{X_S}}^2 + (1 - {\vartheta_{X_S}}^2){\pi_{Y_S}}^2 - {\pi_{X_S}}^2 . {\pi_{Y_S}}^2)^{1/2} \right\} \quad (2)$$

Multiplying with a Scalar: The procedure for multiplying a scalar number by $\lambda > 0$ is as follows.

$$\lambda . X_S = (1 - (1 - {\mu_{X_S}}^2)^{\lambda})^{1/2}, {\vartheta_{X_S}}^{\lambda}, ((1 - {\mu_{X_S}}^2)^{\lambda} - (1 - {\mu_{X_S}}^2 - {\pi_{X_S}}^2)^{\lambda})^{1/2} \quad (3)$$

In addition to the basic operations $X_S = (\mu_{X_S}, \vartheta_{X_S}, \pi_{X_S})$ ve $Y_S = (\mu_{Y_S}, \vartheta_{Y_S}, \pi_{Y_S})$ including $\lambda, \lambda_1, \lambda_2 > 0$ the following conditions are satisfied for SFS.

$$
\begin{aligned}
&\checkmark\ X_S \oplus Y_S = Y_S \oplus X_S \\
&\checkmark\ X_S \otimes Y_S = Y_S \otimes X_S \\
&\checkmark\ \lambda.(X_S \oplus Y_S) = \lambda.X_S \oplus \lambda.Y_S \\
&\checkmark\ \lambda_1.X_S \oplus \lambda_2.X_S = (\lambda_1 + \lambda_2)X_S \\
&\checkmark\ (X_S \otimes Y_S)^{\lambda} = X_S{}^{\lambda} \otimes Y_S{}^{\lambda} \\
&\checkmark\ X_S{}^{\lambda_1} \otimes X_S{}^{\lambda_2} = (X_S)^{\lambda_1 + \lambda_2}
\end{aligned}
\tag{4}
$$

Union: The joining operation between two SFS X_S and Y_S can be described in the following way.

$$X_S \cup Y_S = \left\{ max\{\mu_{X_S}, \mu_{Y_S}\}, min\{\vartheta_{X_S}, \vartheta_{Y_S}\}, max\left\{1 - ((max\{\mu_{X_S}, \mu_{Y_S}\})^2 + (min\{\mu_{X_S}, \mu_{Y_S}\})^2, max\{\mu_{X_S}, \mu_{Y_S}\}\right\}\right\} \tag{5}$$

Intersection: It is possible to express the intersection operation between two SFS X_S and Y_S as follows:

$$X_S \cap Y_S = \left\{ min\{\mu_{X_S}, \mu_{Y_S}\}, max\{\vartheta_{X_S}, \vartheta_{Y_S}\}, min\left\{1 - ((min\{\mu_{X_S}, \mu_{Y_S}\})^2 + (max\{\mu_{X_S}, \mu_{Y_S}\})^2, min\{\mu_{X_S}, \mu_{Y_S}\}\right\}\right\} \tag{6}$$

Score and Accuracy Functions: Score and accuracy are two functions that can be used to evaluate options. An accurate number is obtained from a fuzzy number using this method.

$$Score(X_S) = (\mu_{X_S} - \pi_{X_S})^2 - (\vartheta_{X_S} - \pi_{X_S})^2 \tag{7}$$

$$Accurancy(X_S) = \mu_{X_S}{}^2 + \vartheta_{X_S}{}^2 + \pi_{X_S}{}^2 \tag{8}$$

3.2. Spherical Fuzzy - TOPSIS

A MCDM problem can be expressed as a decision matrixwhose elements indicate the values of all alternatives with respect to each criterion under interval-valued SF environment. Let $X = \{x_1, x_2 \dots . x_m\}$ $(m \geq 2)$ be a discrete set of m feasible alternatives and $C = \{c_1, c_2 \dots . c_m\}$ be a finite set of criteria, and $W = \{w_1, w_2 \dots . w_n\}$ be the weight vector of all criteria which satisfies $0 \leq w_j \leq 1$and $\sum_{j=1}^{n} w_j = 1$.

Step 1: A list of DM' evaluations based on linguistic phrases is created. The scale in Table 1 can be used for this.

Table 1. Linguistic terms and SF Numbers [9]

Linguistic terms	SF Numbers
Absolutely more Importance (AMI)	0,9-0,1-0,1
Very High Importance (VHI)	0,8-0,2-0,2
High Importance (HI)	0,7-0,3-0,3
Slightly More Importance (SMI)	0,6-0,4-0,4
Equally Importance (EI)	0,5-0,5-0,5
Slightly Low Importance (SLI)	0,4-0,6-0,4
Low Importance (LI)	0,3-0,7-0,3
Very Low Importance (VLI)	0,2-0,8-0,2
Absolutely Low Importance (ALI)	0,1-0,9-0,1

Step 2: Because not all criteria are equally important, the weighted average (SWAM) operator is used to combine each DM's assessment of the criteria's value.

$$
\begin{aligned}
SWAM_w(X_{s_1}, \dots, X_{s_n}) &= w_1 X_{s_1} + w_2 X_{s_2} + \dots + w_n X_{s_n} \\
= \Big\{ \big[1 - \textstyle\prod_{i=1}^{n} (1 - \mu_{X_{Si}}{}^2)^{w_i}\big]^{1/2} & \textstyle\prod_{i=1}^{n} \vartheta_{X_{Si}}{}^{w_i}, \big[\textstyle\prod_{i=1}^{n} (1 - \mu_{X_{Si}}{}^2)^{w_i} - \textstyle\prod_{i=1}^{n} (1 - \mu_{X_{Si}}{}^2 - \pi_{X_{Si}})^{w_i}\big]^{1/2}
\end{aligned}
\tag{9}
$$

The opinions of DM's are used to create a SF decision matrix. C_j. in terms of criteria, the $C_j.X_i = (\mu_{ij}, \vartheta_{ij}, \pi_{ij})$ values formed according to the evaluation of the X_i alternative are placed in the matrix and the following D-DECİSİON MATRİXis created.

$$D = (C_j.(X_i))_{mxn} = \begin{pmatrix} \mu_{11}, \vartheta_{11}, \pi_{11} & \cdots & \mu_{1n}, \vartheta_{1n}, \pi_{1n} \\ \vdots & \ddots & \vdots \\ \mu_{m1}, \vartheta_{m1}, \pi_{m1} & \cdots & \mu_{mn}, \vartheta_{mn}, \pi_{mn} \end{pmatrix} \quad (10)$$

Step 3: Starting with the matrix formed in the previous step, the weighted SF matrix is created as follows, after calculating the weight of each criterion and the degree of alternatives.

$$D = (C_j.(X_{iw}))_{mxn} = \begin{pmatrix} \mu_{11w}, \vartheta_{11w}, \pi_{11w} & \cdots & \mu_{1nw}, \vartheta_{1nw}, \pi_{1nw} \\ \vdots & \ddots & \vdots \\ \mu_{m1w}, \vartheta_{m1w}, \pi_{m1w} & \cdots & \mu_{mnw}, \vartheta_{mnw}, \pi_{mnw} \end{pmatrix} \quad (11)$$

Step 4: For each alternative-criteria pair, the weighted SF matrix is clarified, and the score functions are written. The derived score values are used to convert fuzzy values to exact values, yielding ideal solutions.

$$Score\big(C_j.(X_{iw})\big) = (\mu_{ijw} - \pi_{ijw})^2 - (\vartheta_{ijw} - \pi_{ijw})^2 \quad (12)$$

Step 5: The SF positive ideal solution (SF-PIS) and the SF negative ideal solution (SF-NIS) are calculated using the score values.
For the SF-PIS, the highest score for each criterion has value. Then, for the criterion with the greatest score value, the weighted SF value is written.

$$X^* = \{C_j, \max_i \langle Score\big(C_j.(X_{iw})\big)\rangle \mid J = 1,2 \ldots n\}$$
$$X^* = \{\langle C_1, \mu_1{}^*, \vartheta_1{}^*, \pi_1{}^*\rangle, \langle C_2, \mu_2{}^*, \vartheta_2{}^*, \pi_2{}^*\rangle \ldots . \langle C_n, \mu_n{}^*, \vartheta_n{}^*, \pi_n{}^*\rangle\} \quad (13)$$

The lowest score value of each criterion is found for the SF-NIS. Then, for the criterion with the lowest score value, the weighted SF value is written.

$$X^- = \{C_j, \min_i \langle Score\big(C_j.(X_{iw})\big)\rangle \mid J = 1,2 \ldots n\}$$
$$X^- = \{\langle C_1, \mu_1{}^-, \vartheta_1{}^-, \pi_1{}^-\rangle, \langle C_2, \mu_2{}^-, \vartheta_2{}^-, \pi_2{}^-\rangle \ldots . \langle C_n, \mu_n{}^-, \vartheta_n{}^-, \pi_n{}^-\rangle\} \quad (14)$$

Step 6: The distances from SF-PIS and SF-NIS are determined for each (X_i) option. In the calculations, the Euclidean distance formula is utilized. The SF-NIS is calculated using the equation below. As a result, the distance between each criterion and the negative ideal solution is calculated. The greater the distance, the more likely it is that a selection will be made.

$$D(X_i, X^*) = \sqrt{\frac{1}{2n}\sum_{i=1}^{n}((\mu_{xi} - \mu_{x-})^2 + (\vartheta_{xi} - \vartheta_{x-})^2 + (\pi_{xi} - \pi_{x-})^2)} \quad (15)$$

The SF-PIS is calculated using the equation below. As a result, the distance between each criterion and the positive ideal solution is calculated. The closer this distance is, the more likely it is that a selection will be made.

$$D(X_i, X^*) = \sqrt{\frac{1}{2n}\sum_{i=1}^{n}((\mu_{xi} - \mu_{x*})^2 + (\vartheta_{xi} - \vartheta_{x*})^2 + (\pi_{xi} - \pi_{x*})^2)} \quad (16)$$

Step 7: The minimum of the distance to the SF-PIS and the maximum of the distance to the SF-NIS are selected.

$$D_{max}(X_i, X^-) = \max_{1 \le i \le m} D(X_i, X^-) \quad (17)$$

$$D_{min}(X_i, X^*) = \max_{1 \le i \le m} D(X_i, X^*) \quad (18)$$

Step 8: The modified proximity ratio is calculated using the values determined in step 7.

$$\xi((X_i) = \frac{D(X_i, X^-)}{D_{max}(X_i, X^-)} - \frac{D(X_i, X^*)}{D_{min}(X_i, X^*)} \quad (19)$$

Step 9: Alternatives are rated according to their availability, and the best option is chosen based on this ranking. The option with the highest value is chosen as the most appropriate.

4. Results

3PRLP is selected for an aluminum producer business. First, an expert team of three DM (e1, e2, e3) is constituted, consisting of a senior manager, a functional manager, and a process owner. First, the criteria listed in the literature section are studied, and four main criteria and eleven sub-criteria that are applicable and understandable are identified. The criteria are shown in Figure 1.

Criteria	Sub-Criteria	Index value
Reverse Logistics Operations	Collection	Co
	Storage	St
	Transportation	Tr
	Repair	Rp
	Recycle	Rc
	Remanufacture	Rm
Cost	Reverse Logistics cost	Rlc
Experience	Corporate image	Ci
	Industry experience	Ie
Quality	Service Quality	Sq
	Customer Satisfaction	Cs

Figure 1. Criteria

For selection, the organization has identified four RL service providers (R1,R2,R3,R4). In accordance with the established criteria and alternatives, a decision model is developed. Figure 2 shows the decision model structure that is constructed. Below are the steps of the SF-TOPSIS.

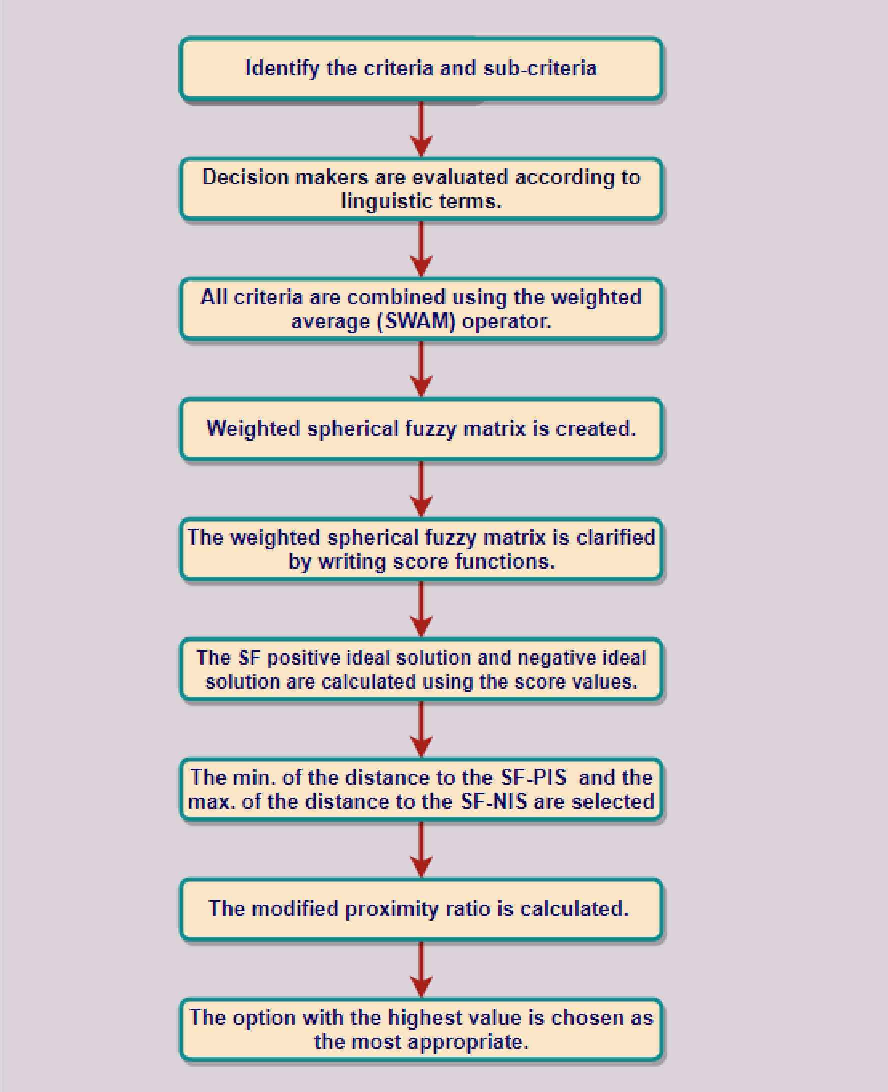

Figure 2. Decision model structure

First, the experts' evaluations are based on the linguistic terms in Table 1 and a table of linguistic variables is generated for each expert. Tables 2, 3, and 4 show the tables that are created for each expert.

Table 2. First expert opinion

	R1	R2	R3	R4
Co	HI	VHI	VHI	HI
St	SMI	VHI	VHI	HI
Tr	HI	HI	SMI	HI
Rp	HI	VHI	EI	EI
Rc	EI	HI	EI	HI
Rm	EI	HI	VHI	HI
Rlc	HI	EI	SMI	VHI
Ci	HI	SMI	EI	VHI
Ie	VHI	SMI	SMI	HI
Sq	HI	HI	EI	HI
Cs	VHI	HI	EI	EI

Table 3. Second expert opinion

	R1	R2	R3	R4

Co	HI	SMI	EI	VHI
St	HI	SMI	EI	VHI
Tr	EI	HI	HI	SMI
Rp	SMI	HI	SMI	HI
Rc	VHI	VHI	SMI	HI
Rm	VHI	VHI	VHI	EI
Rlc	VHI	HI	VHI	VHI
Ci	HI	SMI	HI	HI
Ie	EI	HI	SMI	EI
Sq	HI	HI	EI	HI
Cs	EI	HI	EI	EI

Table 4. Third expert opinion

	R1	R2	R3	R4
Co	VHI	SMI	VHI	EI
St	HI	EI	SMI	VHI
Tr	EI	HI	SMI	HI
Rp	EI	SMI	VHI	HI
Rc	HI	VHI	SMI	EI
Rm	HI	SMI	VHI	VHI
Rlc	VHI	HI	HI	EI
Ci	HI	VHI	VHI	EI
Ie	EI	EI	EI	HI
Sq	EI	VHI	HI	EI
Cs	HI	VHI	HI	HI

Each expert is asked to assess the criteria using the linguistic expressions listed in Table 1. Table 5 presents expert opinions on the criteria.

Table 5. Expert opinions for criteria

	e1	e2	e3
Co	AMI	VHI	VHI
St	HI	VHI	HI
Tr	EI	SMI	HI
Rp	EI	SMI	VHI
Rc	HI	VHI	AMI
Rm	EI	SLI	HI
Rlc	VHI	AMI	AMI
Ci	VHI	EI	HI
Ie	AMI	SMI	HI
Sq	HI	SLI	EI
Cs	HI	HI	VHI

The SWAM operator is used to combine the DM' decisions in the second step. Experts' weights are needed for splicing. According to their seniority and experience, experts are weighted as e1:0,45, e2:0,30, and e3:0,25. The decision matrix is generated by carrying out the SWAM operator operations in Eq 9. Table 6 shows the decision matrix.

Table 6. The decision matrix

	C1	C2	C3	C4
R1	(0,73 0,27 0,27)	(0,66 0,34 0,34)	(0,65 0,35 0,35)	(0,63 0,37 0,37)

R2	(0,72 0,28 0,28)	(0,70 0,30 0,30)	(0,70 0,30 0,30)	(0,73 0,27 0,27)
R3	(0,74 0,26 0,26)	(0,69 0,31 0,31)	(0,64 0,36 0,36)	(0,64 0,36 0,36)
R4	(0,71 0,29 0,25)	(0,76 0,24 0,24)	(0,68 0,32 0,32)	(0,62 0,38 0,38)
	C5	C6	C7	C8
R1	(0,67 0,33 0,33)	(0,67 0,33 0,33)	(0,77 0,23 0,23)	(0,70 0,30 0,30)
R2	(0,67 0,33 0,33)	(0,68 0,32 0,32)	(0,71 0,29 0,29)	(0,68 0,32 0,32)
R3	(0,57 0,43 0,43)	(0,80 0,20 0,20)	(0,66 0,34 0,34)	(0,66 0,34 0,34)
R4	(0,66 0,34 0,34)	(0,69 0,31 0,31)	(0,73 0,27 0,27)	(0,69 0,31 0,31)
	C9	C10	C11	
R1	(0,68 0,32 0,32)	(0,67 0,33 0,33)	(0,71 0,29 0,29)	
R2	(0,62 0,38 0,38)	(0,73 0,27 0,27)	(0,73 0,27 0,27)	
R3	(0,59 0,41 0,41)	(0,65 0,35 0,35)	(0,56 0,44 0,44)	
R4	(0,66 0,34 0,34)	(0,66 0,34 0,34)	(0,56 0,44 0,44)	

The weights of the criteria are calculated in the third step. Each criterion's weights are not equal. Each expert's level of priority for criteria is likewise diverse. Each expert's SF values for criteria are merged for this purpose. The expert team assessed each criterion using linguistic phrases. The evaluation findings are shown in Table 7. The SWAM operator is used to calculate the weight values of the criterion, and equation 9 is used to calculate them. The results are shown in Table 8.

Table 7. The Evaluation

	e1	e2	e3
Co	AMI	VHI	VHI
St	HI	VHI	HI
Tr	EI	SMI	HI
Rp	EI	SMI	VHI
Rc	HI	VHI	AMI
Rm	EI	SLI	HI
Rlc	VHI	AMI	AMI
Ci	VHI	EI	HI
Ie	AMI	SMI	HI
Sq	HI	EI	HI
Cs	HI	HI	VHI

Table 8. Weight Values of The Criterion

	W		
Co	0,85	0,15	0,15
St	0,73	0,27	0,27
Tr	0,59	0,41	0,41
Rp	0,64	0,36	0,36
Rc	0,80	0,20	0,20
Rm	0,54	0,46	0,46
Rlc	0,87	0,13	0,13
Ci	0,71	0,29	0,29
Ie	0,81	0,19	0,19
Sq	0,60	0,40	0,40
Cs	0,73	0,24	0,24

A weighted SF- decision matrix is created in the fourth stage. Equation 2 is used to create a weighted combined decision matrix after the weights of the criterion and the combined DECİSİON MATRİXare generated. The weighted SF decision matrix obtained is shown in Table 9.

Table 9. The Weighted SF- Decision Matrix

C1			C2			C3			C4		
(0,62	0,31	0,30)	(0,48	0,42	0,40)	(0,38	0,52	0,48)	(0,40	0,50	0,46)
(0,61	0,31	0,31)	(0,51	0,40	0,38)	(0,41	0,49	0,46)	(0,47	0,44	0,42)
(0,63	0,30	0,29)	(0,50	0,40	0,38)	(0,38	0,53	0,48)	(0,41	0,49	0,46)
(0,60	0,32	0,28)	(0,55	0,36	0,34)	(0,40	0,50	0,47)	(0,40	0,51	0,47)
C5			C6			C7			C8		
(0,54	0,38	0,37)	(0,36	0,55	0,50)	(0,67	0,26	0,26)	(0,50	0,41	0,39)
(0,54	0,38	0,37)	(0,37	0,54	0,50)	(0,62	0,32	0,31)	(0,48	0,42	0,40)
(0,46	0,47	0,45)	(0,43	0,49	0,48)	(0,57	0,36	0,36)	(0,47	0,44	0,41)
(0,53	0,39	0,38)	(0,37	0,54	0,50)	(0,64	0,30	0,29)	(0,49	0,41	0,39)
C9			C10			C11					
(0,55	0,37	0,36)	(0,40	0,50	0,50)	(0,52	0,37	0,37)			
(0,50	0,42	0,41)	(0,44	0,47	0,44)	(0,53	0,36	0,34)			
(0,48	0,45	0,43)	(0,39	0,51	0,47)	(0,41	0,49	0,47)			
(0,53	0,38	0,37)	(0,40	0,51	0,47)	(0,41	0,49	0,47)			

In the fifth stage, the score function in Eq.12 is written and translated to exact values for each value in the weighted SF- decision matrix. Table 10 shows the value of the score function.

Table 10. The value of the score function

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
R1	0,099	0,003	0,017	0,008	0,024	0,032	0,166	0,008	0,034	0,010	0,022
R2	0,088	0,013	0,005	0,000	0,024	0,028	0,091	0,003	0,007	0,000	0,031
R3	0,110	0,010	0,020	0,006	0,000	0,003	0,045	0,001	0,001	0,013	0,006
R4	0,077	0,040	0,009	0,010	0,019	0,025	0,114	0,005	0,023	0,011	0,006

The score values are used to find SF positive and SF negative ideal solutions. For each criterion, the lowest and greatest values of the score functions are determined. On the score function charts, the values discovered are colored. Yellow represents the one with the highest value according to the Eq.13 formula. Blue represents the lowest value according to the Eq.14 formula.

Positive ideal and negative ideal solutions are the values in the SF decision matrix that correspond to the highest and lowest scores. Table 11 lists the positive and negative solutions found.

Table 11. Positive and Negative Ideal Solutions

C	X^{*}			X^{-}		
Co	0,63	0,30	0,29	0,60	0,32	0,28
St	0,55	0,36	0,34	0,48	0,42	0,40
Tr	0,38	0,53	0,48	0,41	0,49	0,46
Rp	0,40	0,51	0,47	0,47	0,44	0,42
Rc	0,54	0,38	0,37	0,46	0,47	0,45
Rm	0,36	0,55	0,50	0,43	0,49	0,48
Rlc	0,67	0,26	0,26	0,57	0,36	0,36
Ci	0,50	0,41	0,39	0,47	0,44	0,41
Ie	0,55	0,37	0,36	0,48	0,45	0,43
Sq	0,39	0,51	0,47	0,44	0,47	0,44
Cs	0,53	0,36	0,34	0,41	0,49	0,47

Each criterion's distance from the positive ideal and positive negative solutions is calculated at the 6th steps. The Euclidean distance formulas in Eq 15-16 are used to compute the distances of each criterion to SF-NIS and SF-PIS. Table 12 summarizes the findings.

Table 12. Distance Values

Alternatives	$D(X_i, X^*)$	$D(X_i, X^-)$
R1	0,030	0,077
R2	0,043	0,064
R3	0,077	0,030
R4	0,052	0,060

The closeness ratio is calculated in the seventh stage. Table 13 shows how to determine the closeness ratio for each choice using the approach in Eq.19.

Tablo 13. The Closeness Ratio

Alternatives	Proximity Ratios	Ranking
R1	0,000	4
R2	0,602	3
R3	2,177	1
R4	0,954	2

Finally, the closeness ratio values are used to order the data. It is established that R3>R4>R2>R1 when we ranked the companies according to the closeness ratios in the table. The 3PRLP firm with the greatest score is the 3rd Firm, and the 3PRLP firm with the lowest score is the 1th Firm, according to these values.

5. Discussion and Conclusion

The importance of selecting 3PRLPs has grown as firms' outsourcing activities have increased. This has the potential to reduce costs while significantly improving customer service. This paper presents a multi-criteria group decision making method for 3PRLP selection based on SF-TOPSIS. SF-TOPSIS provides a diverse set of preferences as well as independent membership functions. When determining the best solutions, the method employs the score function. The score function takes into account the degree of non-membership, the degree of indecision, and the degree of membership. The ratings of each alternative according to each criterion, as well as the weights of each criterion, are given as linguistic terms denoted by SFnumbers during the evaluation process. In addition, the global fuzzy mean operator is used to collect decision makers' opinions. The relative closeness coefficients of the alternatives are obtained and the alternatives are ranked after calculating the SF positive-ideal solution and the SF negative-ideal solution based on the Euclidean distance.

The proposed model for an aluminum producer business is presented in order to achieve efficiency and effectiveness in RL applications. With the help of three expert teams formed from within the company, four main criteria and eleven sub-criteria are determined. In order to be successful in 3PRLP applications, the company should pay more attention to the RL costs , collection , and industry experience criteria. The proposed approach empowers managers/practitioners to make decisions about 3PRLP implementation in their organizations. The obtained results are discussed with the sector and are found to be significant based on the criteria used.

The proposed method is designed for a single industry. In future studies, this method could be applied to a variety of industries. Furthermore, the proposed method can be compared to various fuzzy numbers, or it can be extended and compared to various MCDM methods using an integrated approach.

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