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PROXIMITY INDEX VALUE FOR SUPPLIER SELECTION USING COMPROMISE WEIGHTING OF STEPWISE WEIGHT ASSESSMENT RATIO ANALYSIS AND THE METHOD OF REMOVAL EFFECTS OF CRITERIA: A CASE STUDY IN INDONESIAN LEATHER INDUSTRY

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ABSTRACT
Procurement of new raw materials is needed when product demand increases, and raw material suppliers must be determined to meet the company's needs. This research examines what criteria a company needs when selecting criteria using Delphi. The weighting of criteria cannot be separated from the element of the decision maker's subjectivity; therefore, it is necessary to compromise between subjective and objective criteria. Therefore, the study used The Method of Removal Effects of Criteria (objective weighting of criteria) and Stepwise Weight Assessment Ratio Analysis (subjective weighting of criteria) in weighting criteria. Then, considering the weight of the criteria, the Proximity Index Value (PIV) is used to evaluate and rate the suppliers. The offered methodology is applied to a real case study from a leather manufacturing company in Indonesia to verify its applicability with a sensitivity analysis performed on different scenarios. The findings indicated that the proposed model is dependable and that the rankings are resilient to fluctuations in the criterion weights.
Keywords: *Supplier Selection, Weighting Of Criteria, Proximity Index, PT. Adi Satria Abadi.*

1. Introduction

Demand for leather products in Indonesia in 2024 will show positive growth, driven by high demand from both domestic and international markets. In the first quarter of 2024, the leather and leather goods industry will experience stable expansion with an industrial performance index above 55%. Increasing raw material requirements must support this progress in demand because raw materials are a fundamental component (Akhtar, 2023). To fulfill these demands, PT Adi Satria Abadi (PT.ASA), one of the largest leather industries in Indonesia, is increasing its capacity to request raw materials from suppliers. This capacity addition requires cooperation from suppliers. Prioritizing supplier quality ensures that products align with businesses' and company's expectations and preferences (Agarwal, 2024; Akburak, 2022; Galankashi et al., 2021; Khanam & Amin, 2022). As stated by the business, every supplier possesses a distinct personality when fulfilling the demands for raw materials (Üstündağ et al., 2022). Hence, choosing suppliers has been recognized as a vital challenge that organizations must address to maintain a strategic competitive advantage (Gupta et al., 2019). More than a mere component, the supplier is an essential determinant of a company's performance, making the selection process even more significant.

Supplier selection is not only for momentary interests but for the success of PT.ASA in the future. Therefore, companies must develop an efficient supply chain to maintain supplier communication (Bag et al., 2023). Good communication with suppliers will ensure that PT. ASA's raw material supply chain is maintained sustainably because supply chain management dramatically influences the company's performance and success (Malde, 2022). Meeting the demand for leather products in Indonesia in the future will be well-managed if companies and suppliers establish positive relationships and maintain a solid supply chain (Üstündağ et al., 2022). Thus, strategic supplier selection is crucial to managing industrial relations effectively (Hesami, 2024; Mtawango, 2024; Muswere, 2022), impacting the continuity of responding to the demand for leather products in Indonesia.

Conducting thorough research is crucial to reduce the probability of the company experiencing disappointment when choosing vendors (Israel et al., 2023). A challenge in multi-criteria decision-making (MCDM) is supplier selection. Therefore, numerous MCDM methods, such as Proximity Indexed Value (PIV), have been employed in studies on supplier selection. The Technique for Order Preference by Similarity to the Ideal Solution (TOPSIS) approach is widely used in the literature to solve Multiple-Criteria Decision-Making (MCDM) problems (Bingol, 2022). However, PIV surpasses TOPSIS regarding rank reversal (Mufazzal & Muzakkir, 2018). Due to the absence of rank reversal, it exhibits more excellent stability and consistency (Goswami et al., 2022),(Behera & Beura, 2023). PIV is a dependable Multiple Criteria Decision Making (MCDM) tools that produce more precise and accurate results compared to other approaches (Goswami et al., 2022),(Behera & Beura, 2023). Ultimately, the PIV methodology is a highly effective and recently developed method for evaluating comparisons (Bingol, 2022). Compared with the Analytical Hierarchy Process (AHP), VIKOR, and COPRAS, the PIV method is simpler, more effective, and more efficient (Khan et al., 2019). It can solve various problems related to ranking and alternative selection (Khan et al., 2019; Yahya et al., 2019). Due to its benefits, it has been widely acknowledged and held in high regard by scholars in several fields of knowledge (Khan et al., 2019; Yahya et al., 2019). Previous studies have demonstrated that PIV yields superior, dependable, and ranked reversal final results compared to conventional methods such as the AHP, COPRAS, TOPSIS, VIKOR, and others (Goswami et al., 2022).

Because of these substantial benefits, some researchers used PIV analytical methods in the MCDM problem. The PIV method requires criteria weights. The weight of this criterion can be obtained from quantitative or qualitative methods. Qualitative weighting methods include the analytic hierarchy process (AHP) (Saaty, 1988), step-wise weight assessment ratio analysis (SWARA) (Keršulienė et al., 2010), SWARA II/modification of SWARA (Keshavarz-Ghorabaee, 2021), etc. Quantitative weighting methods include entropy (Shannon, 1948; Shannon & Weaver, 1949), best-worst method (BWM) (Rezaei, 2015), criteria importance through the inter-criteria correlation (CRITIC) method (Alinezhad & Khalili, 2019), the Method based on the Removal Effects of Criteria (MEREC) (Keshavarz-Ghorabaee et al., 2021), etc.

The PIV was introduced by Mufazzal and Muzakkir (2018) as a solution for the MCDM problem. In its development, further research refined the PIV by integrating qualitative and quantitative criteria weighting. Yahya et al. (2019) utilized entropy-PIV in multi-response optimization. To demonstrate the suitability and effectiveness of the combined AHP-PIV approaches, Khan et al. (2019) provide two instances of addressing website selection challenges. Wakeel et al. (2021) used the BWM–PIV method to select sustainable materials for automotive manufacturing. Khanh and Van-Cuong (2021) combine PIV and Taguchi methods in milling problems. Ulutaş et al. (2021) proposed a grey method in weighting criteria, then integrated the grey proximity indexed value (GPIV) and grey preference selection index (GPSI) to select the location of the warehouse for a supermarket. Ajith et al. (2022) used a suitable method for weighting criteria and PIV to solve a gear material selection and material selection for load-gearing wagon walls. Goswami et al. (2022) utilized MEREC to determine the objective weights of the six criteria and then selected the best renewable energy (RE) sources using PIV. Bingol (2022) proposes AHP and entropy to derive weights of the attributes, whereas the PIV is used to provide ranks to the acids activator. Behera and Beura (2023) propose that AHP and MEREC derive the criteria weights, whereas the PIV is used in the industry's supplier selection. Ersoy and Taslak (2022) used entropy to specify the criteria weights and integration of PIV - Range of Value (ROV) - Grey relational analysis (GRA) - Measurement Alternatives and Ranking according to Compromise Solution (MARCOS) methods using the Copeland method to rank the sustainable energy sector. Do (2024) used LOPCOW to weight the criteria and used different methods to rank universities: PIV, Ranking of Alternatives with Weights of Criterion (RAWEC), Root Assessment Method (RAM), and Simple Ranking Process (SRP).

Multi-criteria evaluation approaches rely on establishing the weights of the criterion (Ginevičius, 2011). Optimal selection of a weighing method is crucial in supplier selection (Ayan et al., 2023), as the requirements weights substantially impact the review results, which need to be considered (Ginevičius, 2011). Therefore, professionals may need assistance delivering reliable information on different solution options in specific practical situations, considering the impact of variables such as the objective environment, professional level, and time parameters (Cheng et al., 2023). Consequently, our work integrated a subjective and objective attribute weight allocation method, directly calculating attribute weights based on evaluation data. The compromised weighing technique aims to reduce the possible bias of a single subjective or objective weight or to address the limitations of the subjective weight when used alone (Mukhametzyanov, 2021). So, the proposed method uses PIV, considering objective and subjective weights to anticipate biased assessment results in supplier selection. This study uses SWARA as a subjective and MEREC as an objective weighting criterion.

Conventional methods for supplier selection calculations overlook the importance of objective weight considerations, resulting in biased assessment outcomes (Chang, 2023). So, this study makes three novel contributions to the supplier selection area. First, it aims to address the limitations of traditional supplier selection methods by incorporating both subjective and objective weights of evaluation criteria to yield more accurate supplier rankings. Second, it proposes a new methodology for integrating Delphi, MEREC, SWARA, and PIV for supplier selection. Last, we find the methodology for the Indonesian leather industry managers to select the new suppliers, which will help meet the demand for leather products in Indonesia, showing positive growth.

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2. Literature Review

2.1. SWARA

The SWARA method for subjective weighting was devised by Keršuliene et al. (2010). This approach is virtually identical to AHP; however, it is more effective in assessing criteria and a more practical approach than the AHP for developing criteria (Keršulienė et al., 2010). It is less complex than AHP due to its simplicity (Karabasevic et al., 2016). In contrast to the AHP methodology, the SWARA method is more computationally efficient than the AHP approach, necessitates fewer pairwise comparisons, and has a more uncomplicated computing procedure (Stanujkic et al., 2015). SWARA is a more straightforward method that allows specialists to express themselves clearly and conveniently (Keshavarz-Ghorabaee, 2021). For example, unlike the AHP and Best-Worst Method (BWM), the SWARA will enable experts to assess the criteria without regard to any specific best or worst criterion, making it easier for experts to provide evaluations and participate more spontaneously (Anam et al., 2022; Rahman et al., 2022; Sharma et al., 2022).

The relative criteria weights derived by the SWARA technique can be precisely demonstrated through the following steps (Stanujkic et al., 2015):

1. The initial step. The criteria for expected relevance are arranged in descending order.
2. Subsequent phase. The answer specifies the relative relevance of criterion j to the antecedent (j-1) criterion, commencing with the second criterion. The comparative importance of average value is the term used for this ratio (S_j) (Keršulienė et al., 2010).
3. Third phase. The coefficient can be determined by the following formula: K_j

$$K_j = \begin{cases} 1 & , j = 1 \\ S_j + 1 & , j > 1 \end{cases} \tag{1}$$

4. Fourth step. The following formula can determine the revised weight q_j:

$$q_j = \begin{cases} 1 & , j = 1 \\ \frac{q_{j-1}}{Kj} & , j > 1n \end{cases} \tag{2}$$

5. Fifth step. The relative weight of the evaluation criteria is determined as follows:

$$W_j = \frac{q_j}{\sum_{k=1}^{n} q_k} \tag{3}$$

Where W_j denotes the relative weight of criterion j.

2.2. MEREC

The MEREC was introduced by Keshavarz-Ghorabaee et al. (2021) as an objective weighting method. The MEREC method is a recently developed technique for assessing weights (Mishra et al., 2022). Compared to entropy and CRITIC, MEREC is a more exact, practical, and accurate objective weighting approach (Goswami et al., 2022). Hence, MEREC and comparable approaches are more appropriate for establishing the objective weights of the evaluated criteria (Debnath et al., 2023). The MEREC approach objectively evaluates the criteria to ascertain relative relevance by employing precise data or a decision matrix (Keshavarz-Ghorabaee et al., 2021). Nevertheless, few research papers have been conducted utilizing MEREC (Ecer & Aycin, 2023).

The following are the phases of weighting criteria using MEREC (Keshavarz-Ghorabaee et al., 2021)(Shanmugasundar et al., 2022):

First step. This phase involves the development of a decision matrix that displays the ratings or values for each possibility concerning each criterion. The elements of this matrix must be greater than zero, as indicated by the notation x_{ij} (x_{ij} > 0). The appropriate procedure should be used to convert any negative values in the decision matrix to positive values. Assume that the decision matrix has the following structure: n alternatives and m criteria.

$$X = \begin{bmatrix} x_{11} & \cdots & x_{1m} \\ \vdots & \ddots & \vdots \\ x_{n1} & \cdots & x_{nm} \end{bmatrix} \quad (4)$$

Step two. Normalize the choice matrix (N). Simple linear normalization is implemented during this phase to adjust the decision matrix's components. The elements of the normalized matrix are denoted by the letters n_{ij}^{x}. Use Eq. (5) if j is a beneficial criterion; use Eq. (6) if j is a cost criterion.

$$n_{ij}^{x} = \frac{\min_{k}(x_{kj})}{x_{ij}} \quad (5)$$

$$n_{ij}^{x} = \frac{x_{ij}}{\max_{k}(x_{kj})} \quad (6)$$

The third step. The aggregate performance of the suppliers can be determined by Eq. (7). Consequently, a logarithmic metric with equal criteria weights is implemented (Das & Chakraborty, 2023). Supplier efficacy is presumed to be enhanced by smaller normalized values.

$$S_i = ln\left[1 + \left[\frac{1}{m}\sum_j \left|ln\langle n_{ij}^{x}\rangle\right|\right]\right] \quad (7)$$

Fourth step. Eq. (8) can be employed to ascertain the performance of the suppliers after each criterion has been eliminated. The performance of the alternatives is evaluated using the same logarithmic scale after each criterion has been removed individually (Das & Chakraborty, 2023).

$$S_i^{*} = ln\left[1 + \left[\frac{1}{m}\sum_{k,k\neq j} \left|ln\langle n_{jk}^{x}\rangle\right|\right]\right] \quad (8)$$

The fifth step. Compute the elimination effect of the j^{th} criterion in this phase using the values from Steps 3 and 4. The outcome of eliminating the j^{th} condition is denoted as E_j. The values of E_j can be determined by employing Eq. (9). The efficacy of the requirements is typically assessed using a primary logarithmic metric with equal weights (Das & Chakraborty, 2023). Conversely, the absolute deviation measure is employed to ascertain the consequences of eliminating each criterion from the decision-making problem.

$$E_j = \sum_j |S_i^* - S_i| \tag{9}$$

The sixth step. Determine the final weights of the criteria. This step calculates the objective weight of each criterion by utilizing the elimination effects (E_j) from Step 5. In the sentences below, the weight of the j^{th} criterion is denoted by w_j^m. Eq. (10 employs the equation that calculates w_j^m.

$$w_j^m = \frac{E_j}{\sum_k k} \tag{10}$$

This investigation offers a compromise approach that evaluates the benefits of both subjective and objective weighing systems (Moradian et al., 2019). In other words, this method utilizes a combination of SWARA and MEREC to assign a weight to the criterion. The combined weights for each criterion are more reasonable than those of (Çalıskan et al., 2013; Moradian et al., 2019). The synthesis weight for the j^{th} criterion is as stated in Chu & Su (2012).

$$W_j = \frac{w_j^m \, x \, w_j^s}{\sum_{j=1}^{n}\left[w_j^m \, x \, w_j^s\right]}; j=1\ldots n \tag{11}$$

Where w_i^m represents the weight of the j^{th} criterion obtained using the MEREC approach, and w_i^s represents the weight of the j^{th} criterion obtained using the SWARA method.

2.4. PIV

Mufazzal and Muzakkir (2018) introduced PIV as a solution for the MCDM problem. This PIV evaluates suppliers by measuring their proximity value, which indicates how much they deviate from the best supplier (Bingol, 2022). Here is the step-by-step process for the computation method (Mufazzal & Muzakkir, 2018):

Step 1: Constructing a decision matrix. The current values will be organized into a decision matrix. Every row of the matrix is dedicated to a supplier, while each column is designated for a criterion.

Step 2: Data normalization. Since X_{ij} values may vary across scales at different j values, they must be scaled to compare them on the same dimension. Data normalization can be formulated using Equation (12).

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \tag{12}$$

Step 3: Calculation of the weighted, normalized decision matrix. The weight value of the supplier i in this research is determined by a compromise weight between MEREC and SWARA, associated with criterion j, as outlined in Equation (13).

$$v_i = w_j {}^* r_i \tag{13}$$

Step 4: Assessment of the Weighted Proximity Index (WPI). The weighted closeness index (u_i) is employed to determine the proximity of each best-available supplier within the decision criteria range. It quantifies the extent to which each supplier deviates from the optimal value, which is determined by selecting the maximum value for positive criteria and the minimum value for negative criteria. The WPI is subsequently determined by subtracting the weighted normalized value from the most incredible value in the range, as outlined in equations (14) and (15). Benefit criteria employ Eq. (14), while non-benefit criteria employ Eq. (15).

$$u_i = v_{max} - v_i \tag{14}$$

$$u_i = v_i - v_{min} \tag{15}$$

Step 5: Calculation of the aggregate closeness value. The weighted closeness values (u_i) associated with each criterion are combined to determine each supplier's aggregate closeness value (d_i). This value indicates the extent to which a supplier is comparable to the finest supplier, which is feasible for the issue. The proximity value is essential for establishing a consistent ranking hierarchy and mitigating reversals. Equation (16) is used to calculate the aggregate closeness value.

$$d_i = \Sigma_{j=1}^{n} u_j \tag{16}$$

Evaluation. The supplier with the lowest overall closeness value (d_i) will be the closest to the best feasible supplier. As the value decreases, the supplier is deemed more valuable. Consequently, the supplier with the lowest (d_i) value will be ranked first, followed by the supplier with a more substantial (d_i) value.

2.5. Discussion on the benefits and limitations of each method

The main difference between MEREC and SWARA is the data source. SWARA uses criteria value data from company decision-makers, which is very subjective. Decision makers assess how important a criterion is compared to other criteria. Meanwhile, MEREC uses historical data on supplier performance according to these criteria, which is very objective. However, both have advantages and disadvantages, so a compromise is necessary.

The MEREC approach utilizes the removal impact on alternatives to ascertain attribute weights (Cheng et al., 2023). The criterion is assigned a more significant weight when its removal significantly impacts the alternative's performance (Keshavarz-Ghorabaee et al., 2021). Therefore, MEREC concentrates on modifying the overall criterion weight by deactivating one criterion while adjusting the weight of another (Ecer & Pamucar, 2022). More specifically, the significance of a criterion is illustrated by a change in criterion weight (Kaya et al., 2023). This property distinguishes MEREC from other objective weighting methods (such as Shannon's entropy, CILOS, and CRITIC) (Ecer & Aycin, 2023). MEREC offers substantial advantages over other objective weighing systems, including a solid mathematical foundation, simplicity of comprehension, and computation (Ecer & Hashemkhani Zolfani, 2022). Additionally, it is neutral and free from inconsistencies, ambiguity, and uncertainty (Mishra et al., 2022). It is devoid of the opinions and judgments of decision-makers (Goswami et al., 2022)(Keleş, 2023)(Das & Chakraborty, 2023). However, MEREC's weakness is that it does not facilitate the assessment of difficult-to-measure factors, such as supplier communication factors, supplier relationships, supplier accessibility, and others.

The SWARA method is applicable when numerous criteria are established under the circumstances (Zolfani & Saparauskas, 2013). Within this SWARA, the criterion's weight is determined by the choices made by the decision-maker (Keshavarz-Ghorabaee et al., 2021). So, this study used Delphi to establish the numerous criteria for supplier selection in the Indonesian leather industry. A prominent feature of the SWARA approach is its ability to quantify experts' assessments of the critical ratio of features while estimating their weights (Zolfani & Saparauskas, 2013). Hence, the process of subjective weighing requires the involvement of competent experts who possess a comprehensive knowledge of pertinent theory and practical experience (Zavadskas & Podvezko, 2016). Professionals can utilize implicit knowledge, experiences, and information (Mardani et al., 2017). In contrast to the AHP and Best-Worst Method (BWM), the SWARA allows experts to evaluate the criteria without considering any particular best or worst criterion. This facilitates experts in providing assessments and participating more freely (Anam et al., 2022; Rahman et al., 2022; Sharma et al., 2022). SWARA outperforms the Full Consistency Method (FUCOM) and MEREC (Debnath et al., 2023) in the computation of subjective criteria weights from expert opinion.

The involvement of elements of subjectivity in decision-makers is prone to biased results. So, simultaneously, objective factors, such as supplier performance data on these criteria, can be considered during the evaluation process and used to ensure an appropriate level of dominance for each criterion (Zavadskas & Podvezko, 2016). However, they require improved precision (Aghdaie et al., 2014). Thus, this research compromises between subjective weighting (SWARA) and objective weighting (MEREC) to increase precision in criteria weighting. So, SWARA can become more advanced while preserving exceptional precision (Debnath et al., 2023). The SWARA method was exclusively designed to estimate the weight of each criterion. Consequently, to establish supplier priority judgments, alternative MCDM approach methodologies must be implemented (Thakkar, 2021). So, this study combined the SWARA with PIV to select suppliers.

3. Research Methods

This investigation, as seen in Figure 1, comprises three stages: (1) selection of supplier criteria, (2) weighting of criteria, and (3) supplier selection. Logically, company decision-makers choose suppliers based on several criteria. Each criterion has a different weight depending on the decision-maker's wishes. Some decision-makers are more concerned with price criteria, but others are more concerned with quality criteria, and so on. Therefore, the first step that must be taken is to determine several criteria as a basis for selecting a supplier. This study uses Delphi because of several advantages. The second step is to give weight to each of these criteria. In this step, this research uses MEREC and SWARA in weighting criteria. The final step is to choose a supplier by considering these criteria and their weights. This research uses PIV because of some advantages.

3.1. First stage: Selection of supplier criteria.

In this first step, the company's decision-maker selects the criteria because the company will select the supplier (Karamaşa et al., 2021). Since the supplier selection process starts from this stage, criteria selection becomes very important (Ali et al., 2023). Therefore, the choice of method for selecting criteria is also crucial (Ristono et al., 2018b). Methods for selecting criteria include the Delphi, statistical (such as Interpretative Structural Model (ISM), Structural Equation Modeling (SEM), Decision Making Trial And Evaluation Laboratory (DEMATEL), Principal Component Analysis (PCA), Analysis of variance (ANOVA)), MCDM (such as AHP), and mixed methods (Ristono et al., 2018a).

Delphi was chosen at this stage because of several advantages. A key advantage of Delphi is that there is no specific requirement for sample size in the literature. Delphi relies on group dynamics rather than statistical power to reach expert consensus (Cafiso et al., 2013). Delphi's further advantage is combining quantitative and qualitative data (Brady, 2015). A second advantage is obtaining expert comments through an open questionnaire (Koskey et al., 2023). Before presenting the synthesis findings to the same panel of experts for their agreement or disagreement, researchers gathered and analyzed expert viewpoints categorized by topic. After multiple rounds of deliberation, an agreement was reached that reflects the collective expert opinion (Hue & Oanh, 2023). During each round, experts can modify their answers. Following exposure to the ideas of other experts or to elucidate perspectives, adjustments may occur (Drumm et al., 2022). An individual external to the panel provided additional assistance; often, a researcher and other specialists did not acknowledge the remarks. Please refer to Laupichler et al. (2023) for further information regarding Delphi.

3.2. Second stage: Weighting of supplier criteria.

The input in the criteria weighting step is the output of the Delphi step, namely criteria. These criteria are weighted using MEREC and SWARA. Both calculations are carried out in parallel. The first step of SWARA is ranking the criteria according to company decision-makers. The second step is determining the comparative importance of each criterion. The third step is to calculate the criterion coefficients using Eq. (1) and the relative weights using Eq. (2). The final step is to determine the subjective weight of the criteria (w_i^s) using Eq. (3).

The initial phase of the MEREC approach involves the development of a decision matrix. A decision matrix is a structured representation of suppliers and their corresponding criteria values, organized in rows and columns using Eq. (4). The decision matrix is then normalized using Eq. (5) and (6) based on the type of criteria. Eq. (5) for beneficial and (6) for non-beneficial criteria. The beneficial criteria are criteria where a higher value is considered better or more desirable. In other words, maximizing the value of beneficial criteria leads to a better outcome. On the other hand, non-beneficial criteria are those where a lower value is preferable. These criteria represent attributes that are best minimized. Then, we determine suppliers' overall performance after removing each criterion in the third and fourth steps, respectively, using Eq. (7) and (8). The objective weighting of criteria (w_i^m) is derived using Eq. (10). Then, this objective weight (w_i^m) is compromised with subjective weight (w_i^s) using Eq. (11).

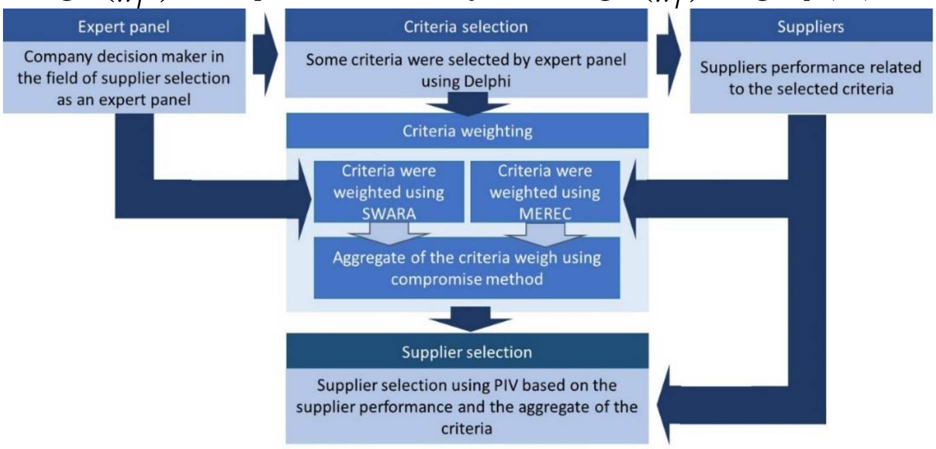


Fig. 1. The proposed method

3.3. Third stage: Supplier selection.

The input in the supplier selection step is supplier performance data (decision matrix) and the output of the criteria weighting step, namely the aggregated weight of the criteria. The first step of the PIV is the same as MEREC, namely the decision matrix formulation. The second step is normalizing the decision matrix using Eq. (12). The weighted normalized decision matrix is created by multiplying the normalized value with the aggregated weights of the criteria, as outlined in Eq. (13). Additionally, the weighted proximity index (WPI) value is defined as the absolute dispersion of each supplier from the finest one, as determined by Eq. (14) and (15). A proximity value, the algebraic sum of the WPI value, is subsequently calculated using Eq. (16). The PIV method has proposed that the proximity value represents the extent to which a supplier deviates from the optimal value. Consequently, the supplier with the least negligible proximity value will be close to the finest supplier and ranked first. The proximity values are used to rank the suppliers in ascending order.

4. Results and Discussions

4.1. Selection of supplier criteria.

The primary goal of the Delphi stage is to gather essential criteria for the firm. Competent professionals managed the submission of questionnaires at this stage. Tables 1 and 2 present the data and results obtained from the Delphi sequential stages. Convergence-based evaluation of the criterion. Table 1 shows that supplier selection considers seven criteria: rejection, delivery, price, communication, complaint method, service, and flexibility.

Standard deviation measures variability or dispersion in a decision maker's data points. Table 2 shows a standard deviation below 1.5. This suggests that the decision-makers responses taken by the instrument are closely clustered around the mean, with minimal spread. This low variability indicates that the instrument is consistent and reliable across measurements or observations. In terms of convergence, a standard deviation below 1.5 suggests that the instrument produces stable results, which is often desirable as the decision maker's data points are not widely scattered. The instrument reliably measures what it is intended to select criteria. So, the result in Table 1 is valid.

Table 2 shows an interquartile range below 2.5. The interquartile range (IQR) is the range within which the middle 50% of the decision-maker's data falls. An IQR below 2.5 indicates that the central half of the decision-maker's responses are close to the median, suggesting minimal variability within this essential data part. A low IQR indicates consistency and reduces the likelihood of extreme outliers affecting the results, implying that the instrument converges well around a central tendency. In other words, most decision-makers' responses are within a small range, which suggests reliability in the measurement process.

In summary, having a standard deviation below 1.5 and an IQR below 2.5 means that the instrument's results are reliable (consistently measured) and precise (with slight variation). This kind of convergence is crucial in validating an instrument for measuring a construct, as it suggests that repeated measurements yield similar values, which can improve confidence in the instrument's utility and accuracy in research or practical applications.

Table 1 – Assessment of criteria.

No	Criteria	Respondent										Mean	Deviation standard
		1	2	3	4	5	6	7	8	9	10		
1	Reject	5	5	4	5	5	4	5	5	5	5	4.782	0.343
2	Delivery	5	5	5	4	4	5	4	4	5	5	4.573	0.302
3	Complaint procedure	5	4	5	4	5	4	5	4	3	3	4.129	0.506
4	Price	5	4	5	4	5	3	5	4	5	4	4.345	0.403
5	Service	3	4	5	4	3	4	3	3	3	5	3.622	1.013
6	Communication	4	5	4	3	4	5	4	5	4	4	4.156	0.777
7	Flexibility	2	3	2	5	4	3	4	4	5	5	3.515	1.440

Table 2 – Result of the Delphi.

first quartile	second quartile	third quartile	Interval of Range (IR)	Quartile Deviation
4.129	4.249	4.573	0.444	0.222

Table 3 – Result of the SWARA.

No	Criteria	Code	Mean	Rating	Relative value of interest level (S_j)	Coefficient of criteria (K_j)	Initial weighting (q_j)	Final weighting of criteria (W_j)
1	Reject	A1	4.782	1		1.000	1.000	0.354
2	Delivery	A2	4.573	2	0.500	1.500	0.667	0.236
3	Price	A3	4.345	3	0.750	1.750	0.381	0.135
4	Communication	A4	4.156	4	1.000	2.000	0.381	0.135
5	Complaint procedure	A5	4.129	5	1.250	2.250	0.169	0.060
6	Service	A6	3.622	6	1.500	2.500	0.169	0.060
7	Flexibility	A7	3.515	7	1.75	2.75	0.062	0.022
	Mean			4	Sum		2.829	1

Table 4 –Decision matrix of the MEREC.

No	Supplier	Criteria						
		Reject	Delivery	Price	Communication	Complaint procedure	Service	Flexibility
1	Cianjur	0.090	4.40	80	70	86	80	95

2	Kediri	0.070	4.20	70	70	90	70	80
3	Lumajang	0.085	5.20	80	80	78	80	90
4	Cirebon	0.080	4.00	60	75	82	70	65
5	Jombang	0.060	5.60	70	70	92	60	55
6	Wonogiri	0.065	5.80	80	70	86	90	70
7	Sidoarjo	0.090	5.00	85	70	80	70	60
8	Rembang	0.060	4.80	75	65	80	60	55

Table 5 –Normalized decision matrix of the MEREC.

No	Supplier	Criteria						
		Reject	Delivery	Price	Communi cation	Complaint procedure	Service	Flexibility
1	Cianjur	1.000	0.759	1.000	1.000	0.935	0.750	0.579
2	Kediri	0.778	0.724	0.875	1.000	0.978	0.857	0.688
3	Lumajang	0.944	0.897	1.000	0.875	0.848	0.750	0.611
4	Cirebon	0.889	0.690	0.750	0.933	0.891	0.857	0.846
5	Jombang	0.667	0.966	0.875	1.000	1.000	1.000	1.000
6	Wonogiri	0.722	1.000	1.000	1.000	0.935	0.667	0.786
7	Sidoarjo	1.000	0.862	1.063	1.000	0.870	0.857	0.917
8	Rembang	0.667	0.828	0.938	1.077	0.870	1.000	1.000

Table 6 –Supplier's performance by deleting each criterion and aggregate performance.

No	Supplier	Criteria							S_i
		Reject	Delivery	Price	Communi cation	Complaint procedure	Service	Flexibility	
1	Cianjur	0.175	0.142	0.168	0.167	0.164	0.140	0.108	0.175
2	Kediri	0.166	0.157	0.173	0.187	0.179	0.178	0.151	0.196
3	Lumajang	0.153	0.147	0.153	0.134	0.160	0.124	0.098	0.160
4	Cirebon	0.162	0.131	0.134	0.159	0.171	0.158	0.156	0.177
5	Jombang	0.065	0.113	0.093	0.108	0.096	0.118	0.118	0.118
6	Wonogiri	0.118	0.159	0.151	0.150	0.147	0.108	0.129	0.159
7	Sidoarjo	0.068	0.048	0.068	0.058	0.064	0.047	0.056	0.068
8	Rembang	0.047	0.076	0.085	0.101	0.098	0.101	0.101	0.101

4.2. Weighting of criteria.

The subjective weight of the criteria is determined via a pairwise comparison computed using SWARA, as shown in Table 3. Meanwhile, objective criteria weighting using MEREC starts from the decision matrix in Table 4. Then, it is normalized in Table 5. The following process is to carry out the impact of elimination for each criterion, as in Tables 6 and 7. The summary of the criteria weight can be seen in Table 8.

Table 3 shows that SWARA's subjective weighting places reject (35.4%) and delivery criteria (23.6%) in the first and second positions, respectively. This indicates that the company places great importance on these two factors compared to other factors. The company emphasizes the percentage of defective raw materials. The company wants all raw materials entering the factory to be of good quality to increase profits. Therefore, companies want suppliers to send raw materials with the lowest possible defect rate. Demand for leather products in Indonesia continued to experience favorable growth in early 2024, resulting in companies being flooded with orders. This increased the speed of the supply of raw materials. Therefore, delivery criteria are also an essential factor besides reject criteria.

The result of the MEREC's objective weighting in the last row in Table 7 shows that the reject (18.2%) and delivery criteria (16.6%) are in the top three. This indicates that suppliers also care about these two factors. They understand that the two factors are the basis for accepting raw materials to increase profits. The flexibility criterion (21.7%) is in first place because the increase in leather products has not been stable in Indonesia, requiring suppliers to be more flexible in dealing with changes in demand. Flexibility is a supplier's strategy to stay afloat in an ever-changing business environment.

The compromise of SWARA's subjective weighting and MEREC's objective weighting (in Table 8) shows reject (43.2%) and delivery criteria (26.2%) in the first and second positions, respectively. This result is very relevant to the results of the two types of weighting above.

These results are in line with the company's expectations and reality. The company's primary goal is to take advantage of opportunities as soon as possible to increase demand for leather products in Indonesia and abroad while gaining greater profits. So, the company wants raw materials from suppliers to meet demand quickly with the smallest number of defects. Therefore, these two criteria should be given the most significant weight. These two criteria are heavily weighted in supplier selection. Suppliers with the best performance in both criteria are likely to be selected. Kediri and Rembang are the number one and two selected suppliers. Both have rejects of 7% and 6% (in Table 4), respectively. Those are the smallest rejects. Both have average delivery dates of 4.2 and 4.8 days (in Table 4). This includes fast shipping. Even though the fastest is 4 days (Cirebon), Cirebon has many rejects (8%). This means that the company is more concerned with rejects than delivery, so the weight of the reject criteria is higher than that of the delivery criteria. So, companies prefer Kediri and Rembang over Cirebon.

Table 7 – Elimination effect of each criterion.

No	Supplier	Criteria						
		Reject	Delivery	Price	Communi cation	Complaint procedure	Service	Flexibility
1	Cianjur	0.000	0.034	0.007	0.009	0.012	0.035	0.068
2	Kediri	0.030	0.039	0.023	0.009	0.017	0.018	0.045
3	Lumajang	0.007	0.013	0.007	0.026	0.000	0.036	0.062
4	Cirebon	0.014	0.046	0.043	0.017	0.006	0.019	0.020
5	Jombang	0.053	0.004	0.025	0.009	0.021	0.000	0.000
6	Wonogiri	0.040	0.000	0.007	0.009	0.012	0.051	0.030
7	Sidoarjo	0.000	0.020	0.000	0.010	0.003	0.021	0.012
8	Rembang	0.054	0.025	0.016	0.000	0.003	0.000	0.000
	Weight	0.182	0.166	0.119	0.082	0.069	0.165	0.217

Table 8 – The summary of the criteria weight.

No	Method	Criteria weight						
		Reject	Delivery	Price	Communi cation	Complaint procedure	Service	Flexibility
1	MEREC	0.182	0.166	0.119	0.082	0.069	0.165	0.217
2	SWARA	0.354	0.236	0.135	0.135	0.060	0.060	0.022
3	Compromise	0.432	0.262	0.107	0.074	0.027	0.066	0.032

Table 5 is the result of data normalization for seven criteria with different data types. Normalization is used to adjust different criteria values. For example, 9% in reject data is the same as 5.8 days in delivery data. This adjustment is necessary so that data in all criteria can be treated equally and all MEREC equations can apply to all data.

The metric in Table 6 represents the disparity between the total performance of the supplier and its performance when a criterion is omitted. For example, Kediri’s aggregate performance is 0.196 (last column in Table 6); if the reject criteria are deleted, then Kediri’s performance is 0.166 (third column in Table 6). So, the elimination effect of the reject criterion for Kediri’s performance is 0.030 (third column in Table 7). The reject weight is the sum of the elimination effect of the reject criterion for all supplier’s performance (last row in Table 7). The greater the effect value of the criterion, the greater the influence of the criterion on supplier performance. So, if these criteria are not taken into consideration when selecting a supplier, then the supplier loses an opportunity equal to the value of the effect of eliminating the criteria. For example, if the decision maker does not use the reject criteria, then Kediri's performance value will decrease by 3%. The MEREC method measures the weight criteria based on how much influence the criteria have on the performance of all suppliers. The greater the influence, the greater the weight of the criteria. Table 7 shows that the performance of Kediri, Cirebon, and Cianjur suppliers is in first, second, and third positions. However, if SWARA's subjective weighting and PIV compromise MEREC's objective weighting, the sequence changes to Kediri, Rembang, and Cirebon. This shows that if the subjective factors of decision-makers are included, the weighting results can change. However, not much because certain factors are measured only using justification from the decision maker.

4.3. Supplier selection.

Tables 9 and 10 contain the PIVs normalization and weighted-normalization results, respectively. Table 11 shows the rank of suppliers. A sensitivity analysis was performed to validate the suggested model's results, as any potential alterations can directly impact this section's sensitivity to changes. Various factors can impact the weights assigned to the criteria. This section conducts a sensitivity analysis to assess the robustness of the ranking system. Four scenarios have been developed for this purpose, and the ranking has been conducted, considering the new weights.

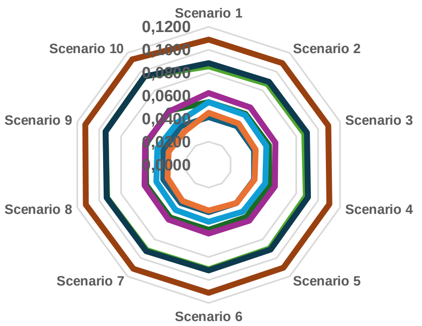
In every situation, the weight of the criterion increases by 2.5%. Figures 2 display the findings. There are no figures that show a clear pattern. Figure 2 indicates that Kediri and Jombang rank higher as the rejection weight increases. The solutions consistently maintain their rankings in all situations based on the data presented. Therefore, the outputs of the suggested model process are highly reliable and can be effectively applied to real-world problems. Even when there are slight variations in the weight of criteria, such as a 20% difference, it does not have any noticeable impact on the method's output.

Table 9 – Normalized decision matrix of the PIV.

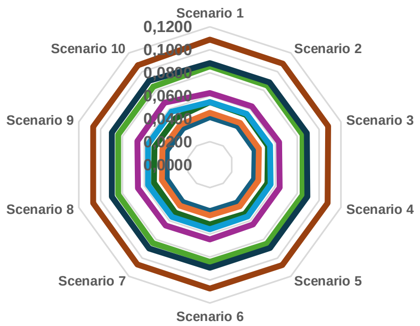
No	Supplier	Criteria						
		Reject	Delivery	Price	Communi cation	Complaint procedure	Service	Flexibility
1	Cianjur	0.419	0.317	0.375	0.347	0.360	0.387	0.462
2	Kediri	0.326	0.302	0.328	0.347	0.377	0.338	0.389
3	Lumajang	0.396	0.374	0.375	0.396	0.327	0.387	0.438
4	Cirebon	0.372	0.288	0.281	0.372	0.344	0.338	0.316
5	Jombang	0.279	0.403	0.328	0.347	0.385	0.290	0.267
6	Wonogiri	0.303	0.417	0.375	0.347	0.360	0.435	0.340
7	Sidoarjo	0.419	0.360	0.399	0.347	0.335	0.338	0.292
8	Rembang	0.279	0.345	0.352	0.322	0.335	0.290	0.267

Table 10 – Weighted decision matrix of the PIV.

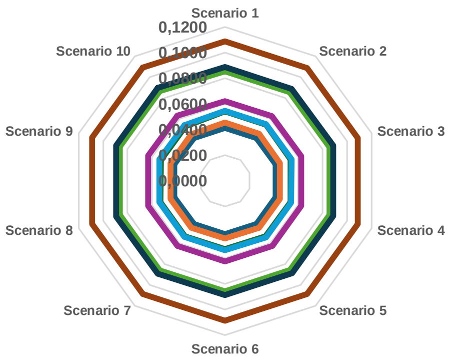
No	Supplier	Criteria						
		Reject	Delivery	Price	Communi cation	Complaint procedure	Service	Flexibility
1	Cianjur	0.181	0.083	0.040	0.026	0.010	0.026	0.015
2	Kediri	0.141	0.079	0.035	0.026	0.010	0.022	0.012
3	Lumajang	0.171	0.098	0.040	0.029	0.009	0.026	0.014
4	Cirebon	0.161	0.075	0.030	0.027	0.009	0.022	0.010
5	Jombang	0.121	0.106	0.035	0.026	0.011	0.019	0.008
6	Wonogiri	0.131	0.109	0.040	0.026	0.010	0.029	0.011
7	Sidoarjo	0.181	0.094	0.043	0.026	0.009	0.022	0.009
8	Rembang	0.121	0.091	0.038	0.024	0.009	0.019	0.008



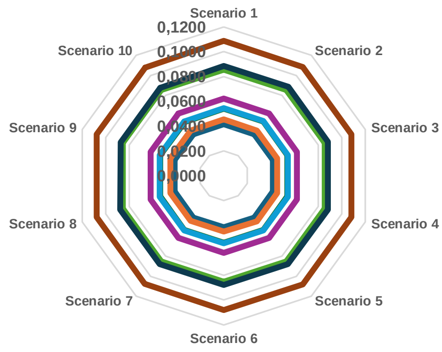
(a) Reject



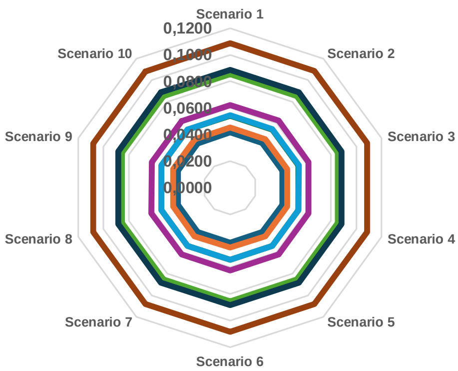
(b) Delivery



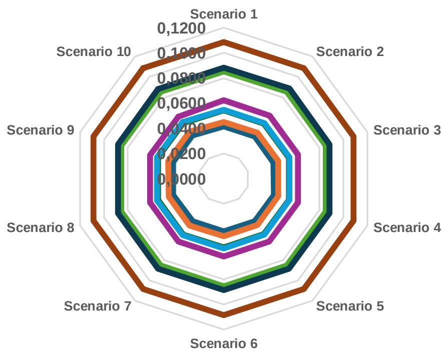
(c) Price



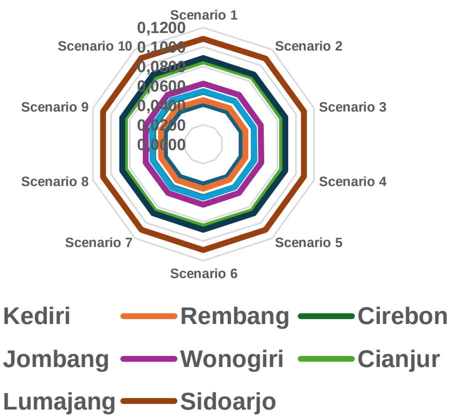
(d) Communication



(e) Complaint procedure



(f) Service



(g) Flexibility

Fig. 2. The sensitivity results

Table 11 –The weighted proximity index (WPI) values and the rank of suppliers.

No	Supplier	Criteria							d_i	Rank
		Quality	Delivery	Price	Communication	Complaint procedure	Service	Flexibility		
1	Cianjur	0.0603	0.0075	0.0100	0.0037	0.0007	0.0032	0.0000	0.0854	6
2	Kediri	0.0201	0.0038	0.0050	0.0037	0.0002	0.0064	0.0023	0.0415	1
3	Lumajang	0.0503	0.0226	0.0100	0.0000	0.0016	0.0032	0.0008	0.0885	7
4	Cirebon	0.0402	0.0000	0.0000	0.0018	0.0012	0.0064	0.0046	0.0542	3
5	Jombang	0.0000	0.0302	0.0050	0.0037	0.0000	0.0096	0.0062	0.0546	4
6	Wonogiri	0.0101	0.0339	0.0100	0.0037	0.0007	0.0000	0.0039	0.0622	5
7	Sidoarjo	0.0603	0.0189	0.0126	0.0037	0.0014	0.0064	0.0054	0.1085	8
8	Rembang	0.0000	0.0151	0.0075	0.0055	0.0014	0.0096	0.0062	0.0452	2

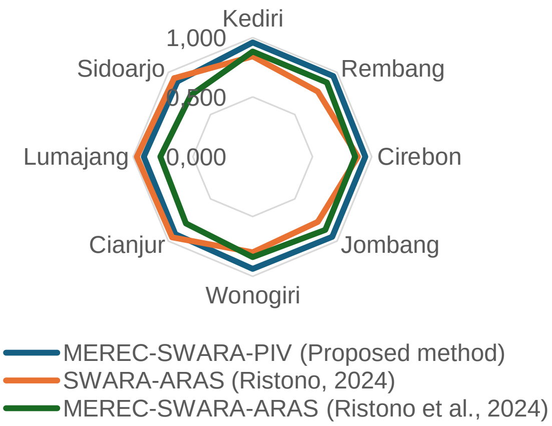


Fig. 3. The comparison results

In this section, we have compared our proposed method to two existing previous research: MEREC-SWARA-ARAS integration (Ristono, 2024) and SWARA-ARAS Integration (Ristono et al., 2024). Figure 3 compares the results of the three methods. The results obtained from MEREC-SWARA-PIV integration (the proposed method) and MEREC-SWARA-ARAS Integration (Ristono, 2024) show almost identical rankings with only minor differences in the overall ranking of suppliers. This is because both methods use subjective and objective weighting simultaneously. Meanwhile, the weight of the criteria greatly determines the results of supplier selection (Ayan et al., 2023). The results obtained from MEREC-SWARA-PIV integration (the proposed method) and SWARA-ARAS Integration (Ristono et al., 2024) show that the rankings are not identical, with significant differences in the overall ranking of suppliers. This is because the last method only uses subjective weighting. Meanwhile, this weighing technique makes the possible bias of a single subjective weight when used alone (Mukhametzyanov, 2021)—this difference in weight results in differences in supplier selection. For example, if the criteria weighting only uses SWARA (Ristono et al., 2024), then the price and communication criteria are equally important and included in the first four orders (Table 8). So, the supplier with the best performance on these two criteria has a significant chance of occupying the first place, namely Lumajang (see red line in Fig.3). Thus, the supplier selection results of the SWARA-ARAS integration method (Ristono et al., 2024) differ from those of the proposed method (MEREC-SWARA-PIV integration).

It can be concluded that this study's new insight into compromising between subjective and objective weighting will result in good supplier selection, even with different MCDM methods (such as PIV or ARAS). Meanwhile, conventional supplier selection methods only have one weight type consideration (Chang, 2023). In addition, the proposed method may give unexpected results, as with the MEREC-ARAS integration method (Ristono et al., 2024). For example, the flexibility criterion has a low weight, and this is following company policy. The company only requires flawless raw materials of the best quality from suppliers. The company's target is to meet the increasing demand for leather products in the future and satisfy customers. Therefore, these two criteria, including the flexibility criterion, are more critical than others.

5. Conclusion

The organization's supply chain efficiency is contingent upon selecting an appropriate supplier. It guarantees customer satisfaction by enabling the timely and cost-effective fulfillment of customer demands. Due to the supplier selection issue in the leather industry, the multi-criteria decision-making instrument was implemented. This approach provides the benefit of partitioning the complex problem into three stages of a straightforward hierarchy: criteria selection, criteria weighting, and supplier selection. The range of change in the main criterion weights was determined through sensitivity analysis, while the ranking of suppliers remained consistent. The rank suppliers for PT. Adi Satria Abadi are Kediri, Rembang, Cirebon, Jombang, Wonogiri, Cianjur, Lumajang, and Sidoarjo.

Due to the growing demand, the company benefited from this investigation in procuring primary materials from suppliers. The management of this organization is firmly persuaded of

the effectiveness of our proposed methodology, which is compelling and easy to implement. They confirmed the efficacy and intricacy of our proposed methodology. Qualitative or quantitative variables may influence supplier selection. Numerous qualitative considerations assess the indispensable factors for selecting a supplier. In our investigation, communication and service were among the variables that proved difficult to quantify.
Several hybrid techniques can address this disparity, such as fuzzy Delphi, fuzzy SWARA, and fuzzy PIV. In the future, analyzing various supply chain sectors and performing an extensive comparison will be feasible, highlighting the challenges in selecting suppliers for these specific sectors.

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