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SUPPLIER RANKING USING MULTIPLE CRITERIA DECISION-MAKING METHODS

Abstract: *Supplier ranking enables businesses to assess objectively the performance, quality, and reliability of their partners, thereby facilitating optimal cooperation choices, minimizing risks, and enhancing operational efficiency. This study ranks eight resin suppliers for a Vietnamese plastics manufacturing company. Each supplier is evaluated against four criteria: unit supply price, delivery time, shipping cost, and supply capacity. Criterion weights were calculated using four different methods: equal weights, entropy, MEREC, and SPC. The supplier rankings were determined using four distinct MCDM (Multiple Criteria Decision-Making) methods: RAM, OPARA, MUTRISS, and TOPSIS. Results indicate that regardless of the weight calculation method or the MCDM method employed, two suppliers consistently emerged as the top performers. Additionally, this study compared the consistency of supplier rankings when various MCDM methods were applied under different weight scenarios. The findings revealed that TOPSIS ranked highest, OPARA and MUTRISS tied for second place, and RAM ranked third.*

Keywords: *resin supplier, MCDM, RAM, OPARA, MUTRISS, TOPSIS, weight*

1. Introduction

Supplier ranking plays a crucial role in business operations. By meticulously evaluating suppliers based on various criteria, such as product quality, price, delivery performance, and customer service, businesses can optimize resources, mitigate risks, and enhance operational efficiency. Collaborating with top-rated suppliers ensures product quality, meets delivery schedules, and strengthens market competitiveness (Abdulla, 2022; Ahmed et al., 2023; Mohammed et al., 2019; George & Balaguru, 2024). Moreover, ranking incentivizes suppliers to continuously improve product quality and service to achieve higher positions (Zarhaoui et al., 2022; Sushil et al., 2024; Chaghooshi et al., 2015). Additionally, supplier ranking aims to eliminate unethical suppliers (Azadfallah, 2016), minimize risks (Fakhrzad et al., 2020), and contribute to sustainability goals such as zero waste (Goli et al., 2023).

The plastics manufacturing industry is pivotal in modern life. With their flexibility, diversity, and ease of processing, plastics have become indispensable in producing a wide range of products, from household items and packaging to electronics, automobiles, and more (Pilapitiya & Ratnayake, 2024). Plastics have significantly improved our lives by providing lightweight, durable, and versatile products. However, the non-

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biodegradable nature of plastics poses significant environmental challenges. Effective plastics management and recycling are imperative for the sustainable development of this industry and for environmental protection (Moshood et al., 2022).

Selecting resin suppliers, in particular, and suppliers in general, is a critical decision that directly impacts a company's production efficiency and final product quality. Beyond product quality, other factors, such as price, delivery time, and supply stability, must be considered. However, these factors vary among suppliers and sometimes even contradict each other, making supplier ranking and selection a challenging task (Evcioğlu, 2023). *MCDM* is a well-known technique for addressing problems involving conflicting criteria among alternatives (Azadfallah, 2014; Azadfallah, 2015; Zahar Djordjevic et al., 2020).

In this study, four *MCDM* methods, namely *RAM*, *OPARA*, *MUTRISS*, and *TOPSIS*, were employed to rank resin suppliers for a Vietnamese plastics manufacturing company. The rationale behind selecting these methods will be elaborated in Chapter 2. To apply these *MCDM* methods for supplier ranking, it is essential to assign weights to the criteria. Four weighting methods, including equal weights, entropy, *MEREC*, and *SPC*, were used in this research. The reasons for choosing these weighting methods will also be discussed in Chapter 2.

Chapter 2 provides a comprehensive literature review on the application of *MCDM* methods in supplier selection. It will also justify the selection of the specific *MCDM* methods (*RAM*, *OPARA*, *MUTRISS*, and *TOPSIS*) and weighting methods (equal weights, entropy, *MEREC*, and *SPC*) used in this study. The steps involved in applying each MCDM and weighting method are presented in Chapter 3. Chapter 4 presents the ranking results of eight resin suppliers for a Vietnamese plastics manufacturing company. The study's conclusion is presented in the final chapter.

2. Literature Review

Every specific field gives rise to a diverse range of suppliers. This necessitates supplier ranking to select the most suitable ones. To achieve this, numerous *MCDM* methods have been applied to various problems (Nguyen et al., 2023; Varela et al., 2024). Some studies have utilized a single *MCDM* method, such as *WASPAS*, for ranking suppliers in a stainless steel plant (Yazdani et al., 2016), healthcare service providers (Debnath et al., 2023), and the furniture industry (Galińska & Rossi, 2018). Other studies have employed *COBRA* for steel industries (Verma et al., 2022) and *DEA* for the oil production sector (Wang et al., 2020), etc.

However, several reports have highlighted that rankings may vary when different *MCDM* methods are applied. Therefore, to ensure decision accuracy, it is advisable to apply at least two *MCDM* methods simultaneously for each specific problem (Alpay & Iphar, 2018; Ha, 2023). This approach has been implemented in many supplier ranking studies.

Many *MCDM* methods have exhibited similar performance in supplier ranking. *TOPSIS* and *SECA*, for instance, have shown comparable results in aerospace and defense (Rasmussen et al., 2023). *TOPSIS*, *MABAC*, *EDAS*, *ARAS*, and *WASPAS* have been used for the iron and steel industry, demonstrating similar performance (Chattopadhyay et al., 2022). Fuzzy *TOPSIS*, fuzzy *VIKOR*, and fuzzy *MULTIMOOR* have also shown comparable results in a foundry (Calik, 2020). *RAPS*, *TOPSIS*, *MOORA*, and *VIKOR* have been jointly used to rank investment firms, indicating similar performance (Alamoudi & Bafail, 2022). *TOPSIS* and *VIKOR* have been used together for transportation services, and their performance has been proven to be similar (Servaite et al., 2020). *MAIRCA*, *CRADIS*, *COPRAS*, *OCRA*, *PIV*, and *TOPSIS* have demonstrated similar performance when applied to insurance service providers (Işık et al., 2024). Six methods, including *SAW*, *ARAS*, *CRADIS*, *MABAC*, *WPM*, and *MARCOS*, have exhibited similar performance in ranking green suppliers for the furniture industry (Chen et al., 2023), etc.

Nevertheless, some reports reveal varying performances of different methods in specific cases. For instance, *TOPSIS*, *PROMETHEE*, *SAW*, and *COPRAS* have outperformed *LINASIGN* in green economy supplier ranking (Agarwal et al., 2023). *SAW* has shown advantages over *TOPSIS* in ranking oil production suppliers in Iran (Darvazeh et al., 2022). In a compressor manufacturing company, *COPRAS-G* has outperformed Fuzzy *VIKOR* (Reza et al., 2023). A new method called *TOPKOR*, a combination of *TOPSIS* and *VIKOR*, has been proven to outperform both *TOPSIS* and *VIKOR* in ranking suppliers for digital stores (Beheshtinia et al., 2022), etc.

The aforementioned information reinforces the notion that multiple *MCDM* methods should be employed in specific supplier ranking cases. However, the abundance of *MCDM* methods makes selecting the appropriate ones challenging (El-Araby et al., 2024). *TOPSIS* has been frequently used in numerous studies, often exhibiting performance comparable to other *MCDM* methods. It has even been identified as the most widely used *MCDM* method (Do, 2021a; Do, 2021b). Moreover, *TOPSIS* has been independently applied in various industries, including heavy industry (Dharun Prashanth et al., 2020), parts manufacturing (Memari et al., 2019), steel (Wang et al., 2022), television manufacturing (Singh et al., 2012), and medical equipment (Tadić et al., 2014). Based on this evidence, *TOPSIS* was selected for this study. However, as previously mentioned, multiple *MCDM* methods are recommended for supplier ranking; thus, this study also employs three additional methods: *RAM*, *OPARA*, and *MUTRISS*.

RAM, introduced in September 2023, considers the balance between criteria (Sotoudeh-Anvari, 2023) and has proven effective with various normalization methods (Trung et al., 2024a). While relatively new, *RAM* has been applied in diverse fields such as fire-resistant material selection (Trung, 2024), mushroom cultivation selection (Trung et al., 2024b), university ranking (Do, 2024), and bank financial health assessment (Trung et al., 2024c). However, no studies have applied *RAM* to supplier ranking, particularly in the plastics industry. *OPARA*, introduced in June 2024, has yet to be applied in published literature (Mehdi et al., 2024). *MUTRISS*, introduced in October 2023, is unique in ranking alternatives based on a space with dimensions equal to the number of criteria, making it transparent and less complex (Zakeri et al., 2023). Due to the abundance of *MCDM* methods and its recent introduction, *MUTRISS* has not received significant attention from researchers. Limited research has been published on *MUTRISS* applications. The novelty of *RAM*, *OPARA*, and *MUTRISS* in supplier ranking, combined with the proven success of *TOPSIS*, makes this study both innovative and grounded in previous research. This is why these four methods are used simultaneously in this study.

When using *RAM*, *OPARA*, *MUTRISS*, and *TOPSIS* for supplier ranking, assigning weights to criteria is essential. To obtain the most generalizable results, four weighting methods were used: equal weights, entropy, *MEREC*, and *SPC*. Equal weights are the simplest method, while entropy and *MEREC* are widely used and recommended methods (Trung & Thinh, 2021). *SPC*, introduced in 2023, is a new method (Gligorić et al., 2023).

3. Materials and Methods

3.1. RAM Method

The *RAM* method was employed to rank alternatives following these steps (Sotoudeh-Anvari, 2023):

*Step 1***:** Construct a decision matrix with *m* rows and *n* columns. Here, *m* represents the number of alternatives to be ranked, and *n* denotes the number of criteria for each alternative. Let x_{ij} represent the value of criterion *j* for alternative *i*, where $j = 1$ to *n*, and $i = 1$ to *m*. The letters *B* and *C* are used to denote benefit criteria and cost criteria, respectively.

Step 2: Normalize the data using Equation (1).

$$r_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \quad (1)$$

Step 3: Calculate the weighted normalized values using Equation (2). Where w_j is the weight of the j^{th} criterion.

$$y_{ij} = w_j \cdot r_{ij} \quad (2)$$

Step 4: Calculate the sum of the weighted normalized values using Equations (3) and (4).

$$S_{+i} = \sum_{j=1}^{n} y_{+ij} \quad if \quad j \in B \quad (3)$$

$$S_{-i} = \sum_{j=1}^{n} y_{-ij} \quad if \quad j \in C \quad (4)$$

Step 5: Calculate the score of each alternative using Equation (5). Rank the alternatives in descending order of their scores.

$$RI_i = \sqrt[2+S_{-i}]{2 + S_{+i}} \quad (5)$$

3.2. OPARA Method

The steps involved in using the *OPARA* method to rank alternatives are as follows (Mehdi et al., 2024):

Step 1: Similar to Step 1 of the *RAM* method.

Step 2: Determine the range-based pairwise adjusted ratio (*RPAR*) between the k^{th} and l^{th} alternatives using Equation (6).

In Equation (6), p_j is the adjustment factor in *RPAR*, calculated using Equation (7).

In Equation (7), the values of α and β are typically set to 5 and 0.8, respectively (Mehdi et al., 2024).

Step 3: Determine the linearity-based pairwise adjusted ratio (*LPAR*) between the k^{th} and l^{th} alternatives using Equation (8).

$$RPAR_{kl} = \sum_{j \in B} w_j \cdot \left(\frac{x_{kj}}{x_{lj}}\right)^{p_j} + \sum_{j \in C} w_j \cdot \left(\frac{x_{lj}}{x_{kj}}\right)^{p_j}, \quad k, l \in \{1, 2, \dots, n\} \quad (6)$$

$$\rho_j = \begin{cases} \dfrac{(\alpha - 1)\max(x_{ij}) + \min(x_{ij})}{\alpha \cdot \max(x_{ij})} & if \quad \dfrac{\max(x_{ij}) - \min(x_{ij})}{\max(x_{ij}) + \min(x_{ij})} > \beta \\ 1 & otherwise \end{cases} \quad (7)$$

$$LPAR_{kl} = \sum_{j \in B} w_j \cdot \left(\frac{x_{kj}}{x_{lj}}\right)^{\tau_j} + \sum_{j \in C} w_j \cdot \left(\frac{x_{lj}}{x_{kj}}\right)^{\tau_j}, \quad k, l \in \{1, 2, \dots, n\} \quad (8)$$

The value of t_j in Equation (8) is determined by the decision-maker. For linear criteria, t_j is set to 1. To increase *LPAR*, t_j is set to a value greater than 1, and to decrease *LPAR*, t_j is set to a value less than 1.

Step 4: Calculate the aggregated pairwise adjusted ratios ($APAR_{kl}$) using Equation (9). In this equation, $\omega \in [0, 1]$ and is typically set to 0.5.

$$APAR_{kl} = \omega \cdot RPAR_{kl} + (1 - \omega) LPAR_{kl} \quad (9)$$

Step 5: Calculate the scores of the alternatives using Equation (10). The alternative with the highest score ranks first.

$$S_i = \frac{1}{n}\left(\sum_{l=1}^{n}\left(\frac{APAR_{il}}{\sum_{k=1}^{n} APAR_{kl}}\right)\right) \quad (10)$$

3.3. MUTRISS Method

The *MUTRISS* method ranks alternatives according to the following steps (Zakeri et al., 2023):

Step 1: Similar to Step 1 of the *RAM* method.

Step 2: Normalize the data using Equations (11) and (12).

$$\bar{x}_{ij} = \frac{x_{ij}}{max(x_{ij})} \quad ij \quad j \in B \tag{11}$$

$$\bar{x}_{ij} = \frac{min(x_{ij})}{x_{ij}} \quad ij \quad j \in C \tag{12}$$

Step 3: Construct a normalized matrix considering the weights of the criteria using Equation (13).

$$r_{ij} = w_j \times \bar{x}_{ij} \tag{13}$$

Step 4: Calculate the scores of the alternatives using Equation (14). The alternative with the highest score ranks first.

$$AV_i = \left(\left(\sum\nolimits_{j=1}^{n} r_j \times r_{(j+1)}\right) + (r_1 + r_n)\right) \times sin\emptyset 0.5 \quad j+1 \le n \tag{14}$$

3.4. TOPSIS Method

The steps involved in using the *TOPSIS* method to rank alternatives are as follows (Do, 2021a):

Step 1: Similar to Step 1 of the *RAM* method.

Step 2: Determine the normalized values using the Equation (15).

$$n_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{n} x_{ij}^2}} \tag{15}$$

Step 3: Calculate the weighted normalized values using the Equation (16)

$$Y = w_j . n_{ij} \tag{16}$$

Step 4: Identify the positive ideal solution (A^+) and the negative ideal solution (A^-) for each criterion using the following two Equations (17) and (18).

$$A^+ = \{y_1^+, y_2^+, \dots, y_j^+, \dots, y_n^+\} \tag{17}$$

$$A^- = \{y_1^-, y_2^-, \dots, y_j^-, \dots, y_n^-\} \tag{18}$$

Where and are the best and worst values of the normalized value y of the j^{th} criterion, respectively.

Step 5: Determine the values of and using the following two Equations (19) and (20).

$$\boldsymbol{S_i^+} = \sqrt{\sum_{j=1}^{n} (\boldsymbol{y_{ij}} - \boldsymbol{y_j^+})^2} \quad i = 1, 2, \dots, m \tag{19}$$

$$\boldsymbol{S_i^-} = \sqrt{\sum_{j=1}^{n} (\boldsymbol{y_{ij}} - \boldsymbol{y_j^-})^2} \quad i = 1, 2, \dots, m \tag{20}$$

Step 6: Calculate the scores of the alternatives using Equation (21). The alternative with the highest score is ranked as the best.

$$\boldsymbol{C_i^*} = \frac{S_i^-}{S_i^+ + S_i^-} \quad \text{i = 1, 2; m; } 0 \le C_i^* \le 1 \tag{21}$$

3.5. Weighting methods for criteria

Equal weights method: The weights of the criteria are calculated using the following Equation (Do, 2021a).

$$w_j = \frac{1}{n} \tag{20}$$

Entropy weighting method: The weights of the criteria are calculated by sequentially applying Equations (21) to (23) (Trung & Thinh, 2021).

$$n_{ij} = \frac{x_{ij}}{m + \sum_{i=1}^{m} x_{ij}^2} \tag{21}$$

$$e_j = \sum\nolimits_{i=1}^{m} \left[n_{ij} \times \ln(n_{ij})\right] - \left(1 - \sum\nolimits_{i=1}^{m} n_{ij}\right) \times \ln\left(1 - \sum\nolimits_{i=1}^{m} n_{ij}\right) \tag{22}$$

$$w_j = \frac{1 - e_j}{\sum_{j=1}^{m}(1 - e_j)} \quad (23)$$

MEREC weighting method: The weights of the criteria are calculated by sequentially applying Equations (24) to (29) (Trung & Thinh, 2021).

$$n_{ij} = \frac{min y_{ij}}{y_{ij}} \quad if \quad j \epsilon B \quad (24)$$

$$n_{ij} = \frac{y_{ij}}{max\, y_{ij}} \quad if \quad j \epsilon C \quad (25)$$

$$S_i = Ln\left[1 + \left(\frac{1}{n}\sum_j^n \left|ln(n_{ij})\right|\right)\right] \quad (26)$$

$$S'_{ij} = Ln\left[1 + \left(\frac{1}{n}\sum_{k,k\neq j}^n \left|ln(n_{ij})\right|\right)\right] \quad (27)$$

$$E_j = \sum_i^m \left|S'_{ij} - S_i\right| \quad (28)$$

$$w_j = \frac{E_j}{\sum_k^m E_k} \quad (29)$$

SPC Weighting Method: The weights of the criteria are calculated by sequentially applying Equations (30) to (34) (Gligorić et al., 2023).

$$SPC_j = \frac{\max(x_{ij}) + \min(x_{ij})}{2};\ \text{i = 1, 2, …, m; } \forall \text{ j} \in [1 \div \text{n}] \quad (30)$$

$$D = \left|d_{ij}\right|_{mxn} = \begin{bmatrix} |x_{11} - SPC_1| & |x_{12} - SPC_2| & \cdots & |x_{1n} - SPC_n| \\ |x_{21} - SPC_1| & |x_{22} - SPC_2| & \cdots & |x_{2n} - SPC_n| \\ \cdots & \cdots & \cdots & \cdots \\ |x_{m1} - SPC_1| & |x_{m2} - SPC_2| & \cdots & |x_{mn} - SPC_2| \end{bmatrix} \quad (31)$$

$$R = \left[r_{ij}\right]_{m\times n} = \begin{bmatrix} \left|\frac{\sum_{i=1}^m d_{i1}}{m \times x_{11}}\right| & \left|\frac{\sum_{i=1}^m d_{i2}}{m \times x_{12}}\right| & \dots & \left|\frac{\sum_{i=1}^m d_{in}}{m \times x_{1n}}\right| \\ \left|\frac{\sum_{i=1}^m d_{i1}}{m \times x_{21}}\right| & \left|\frac{\sum_{i=1}^m d_{i2}}{m \times x_{22}}\right| & \dots & \left|\frac{\sum_{i=1}^m d_{in}}{m \times x_{2n}}\right| \\ \dots & \dots & \dots & \dots \\ \left|\frac{\sum_{i=1}^m d_{i1}}{m \times x_{m1}}\right| & \left|\frac{\sum_{i=1}^m d_{i2}}{m \times x_{m2}}\right| & \dots & \left|\frac{\sum_{i=1}^m d_{in}}{m \times x_{mn}}\right| \end{bmatrix} \quad (32)$$

$$Q = \left[q_{1j}\right]_{1\times n} = \left[\frac{\sum_{i=1}^m r_{i1}}{m} \quad \frac{\sum_{i=1}^m r_{i2}}{m} \quad \dots \quad \frac{\sum_{i=1}^m r_{in}}{m}\right] \quad (33)$$

$$W = \left[w_{1j}\right]_{1\times n} = \left[\frac{q_1}{\sum_{j=1}^n q_j} \quad \frac{q_2}{\sum_{j=1}^n q_j} \quad \dots \quad \frac{q_j}{\sum_{j=1}^n q_j}\right] \quad (34)$$

4. Results and Discussion

Table 1 summarizes the information of eight plastic resin suppliers for a Vietnamese company manufacturing plastic spray bottles. The resin quality of these eight suppliers is considered equal. These eight suppliers are denoted as alternatives *A1*, *A2*, *A3*, *A4*, *A5*, *A6*, *A7*, and *A8*. Each supplier is characterized by four criteria: unit price (*C1*), delivery time (*C2*), shipping cost per shipment (*C3*), and supply capacity (*C4*). *C1*, *C2*, and *C3* are cost criteria, while *C4* is a benefit criterion. The units of these criteria are also clearly shown in Table 1. Notably, *VNĐ* is the Vietnamese currency unit, with one *US* dollar equivalent to approximately 23,500 *VNĐ*.

As observed in Table 1, suppliers *A1* and *A6* have the lowest *C1* value (13,000 *VNĐ*), supplier *A5* has the lowest *C2* (2 days), supplier *A8* has the lowest *C3* (6,000 VNĐ/shipment), and supplier *A1* has the highest *C4* (10,000 tons). Therefore, it is impossible to identify a supplier that simultaneously minimizes *C1*, *C2*, and *C3* while maximizing *C4*. Instead, the goal is to select a supplier that minimizes *C1*, *C2*, and *C3* while maximizing C4 to the greatest extent possible. To achieve this, it is necessary to assign weights to the criteria and employ the *RAM*, *OPARA*, *MUTRISS*, and *TOPSIS* methods to rank the suppliers.

By applying the weighting methods presented earlier (Equations 20 to 34), the weights of the criteria were calculated and summarized in Table 2. It is observed that the weights of the criteria vary significantly when calculated using different methods, with the weight of *C1* varying by up to 223.61%.

The *MCDM* methods presented above were applied to rank the suppliers using *RAM*, *OPARA*, *MUTRISS*, and *TOPSIS*. In each case, the Spearman rank correlation coefficient (S) was calculated to compare the rankings of the suppliers when different weighting methods were used. The value of S is calculated according to Equation (35), where D_i is the difference in the rank of alternative i when ranked using different methods (Kizielewicz & Bączkiewicz, 2021; Aazagreyir et al., 2024).

$$S = 1 - \frac{6D_i^2}{\mathrm{m}(m^2 - 1)} \tag{35}$$

The ranking results of the suppliers using different methods, as well as the S values in each case, are presented in Tables 3 to 10.

Table 1. Plastic resin suppliers (Kizielewicz & Bączkiewicz, 2021)

Alt.	*C1*	*C2*	*C3*	*C4*
	VNĐ	day	VNĐ/ shipment	ton
	C	C	C	B
A1	13000	3	80500	100000
A2	13500	4	65500	90000
A3	15000	3	100000	95000
A4	14000	4	90000	70000
A5	15500	2	85000	85000
A6	13000	5	65000	95000
A7	14000	3	85000	75000
A8	16000	3	60000	65000

Table 2. Weights of the criteria

Weight method	*C1*	*C2*	*C3*	*C4*
Equal	0.2500	0.2500	0.2500	0.2500
Entropy	0.2149	0.3554	0.2148	0.2148
MEREC	0.1118	0.4122	0.2402	0.2359
SPC	0.1194	0.4018	0.2483	0.2306
Max/min	223.61%	164.88%	116.39%	116.39%

Table 3. Ranking of alternatives using the RAM method

Alt.	Equal	Entropy	MEREC	SPC
A1	1	1	2	2
A2	3	4	5	5
A3	4	3	3	3
A4	8	8	8	8
A5	2	2	1	1
A6	5	7	7	7
A7	7	6	6	6
A8	6	5	4	4

Table 4. Spearman correlation coefficient between scenarios when ranking alternatives using the RAM method

Method	Equal	Entropy	MEREC	SPC
Equal	1	0.9048	0.8095	0.8095
Entropy		1	0.9524	0.9524
MEREC			1	1
SPC				1

Table 5. Ranking of alternatives using the OPARA method

Alt.	Equal	Entropy	MEREC	SPC
A1	2	2	2	2
A2	3	3	4	4
A3	6	6	5	5
A4	8	8	8	8
A5	1	1	1	1
A6	4	5	6	6
A7	7	7	7	7
A8	5	4	3	3

Table 6. Spearman correlation coefficient between scenarios when ranking alternatives using the OPARA method

Method	Equal	Entropy	MEREC	SPC
Equal	1	0.9762	0.8810	0.8810
Entropy		1	0.9524	0.9524
MEREC			1	1
SPC				1

Table 7. Ranking of alternatives using the MUTRISS method

Alt.	Equal	Entropy	MEREC	SPC
A1	1	2	2	2
A2	3	3	4	4
A3	6	7	7	7
A4	8	8	8	8
A5	2	1	1	1
A6	4	5	5	5
A7	7	6	6	6
A8	5	4	3	3

Table 8. Spearman correlation coefficient between scenarios when ranking alternatives using the MUTRISS method

Method	Equal	Entropy	MEREC	SPC
Equal	1	0.9286	0.8810	0.8810
Entropy		1	0.9762	0.9762
MEREC			1	1
SPC				1

Table 9. Ranking of alternatives using the TOPSIS method

Alt.	Equal	Entropy	MEREC	SPC
A1	2	2	2	2
A2	6	6	6	6
A3	5	5	5	5
A4	8	7	7	7
A5	1	1	1	1
A6	7	8	8	8
A7	4	4	4	4
A8	3	3	3	3

Table 10. Spearman correlation coefficient between scenarios when ranking alternatives using the TOPSIS method

Method	Equal	Entropy	MEREC	SPC
Equal	1	0.9762	0.9762	0.9762
Entropy		1	1	1
MEREC			1	1
SPC				1

According to the data in Tables 3, 5, 7, and 9, alternatives *A1* and *A5* are consistently identified as the two best alternatives, regardless of the *MCDM* method used for ranking or the weighting method employed. This result leads to the strong conclusion that *A1* and *A5* are the two best suppliers among the eight surveyed suppliers. Additionally, the data in these tables shows that *A4* is consistently considered the worst alternative when using the *RAM*, *OPARA*, and *MUTRISS* methods, regardless of the weighting method. When using the *TOPSIS* method, *A4* is identified as the worst when using the Equal weighting method, while it is ranked *7th* when using the other three weighting methods (Entropy, *MEREC*, and *SPC*). This result is sufficient to conclude that *A4* is a poor alternative and should not be selected. It is noteworthy that when using different weighting methods, the weights of the criteria vary significantly, with the weight of *C1* varying by up to 223.61%, the weight of *C2* by up to 164.88%, and the weights of *C3* and *C4* by up to 116.39% (see Table 2). This further reinforces the conclusion that *A1* and *A5* are the preferred alternatives, while *A4* is the worst alternative and should be avoided.

According to the data in Tables 4, 6, 8, and 10, when using different weighting methods, the Spearman correlation coefficient between these scenarios for the *RAM* method is between 0.8095 and 1, for the *OPARA* method is between 0.8809 and 1, for the *MUTRISS* method is also between 0.8809 and 1, and for the *TOPSIS* method is between 0.9761 and 1. This indicates a high degree of consensus in the ranking of alternatives when the weights of the criteria are calculated using different methods (Keshavarz Ghorabaee et al., 2016). This means that all four methods, *RAM*, *OPARA*, *MUTRISS*, and *TOPSIS*, are suitable for ranking plastic resin suppliers in this study. However, when comparing the consistency of the rankings of alternatives more closely when ranked using different *MCDM* methods under different weighting scenarios, *TOPSIS* ranks first, *OPARA* and *MUTRISS* rank second, and *RAM* ranks third. This ranking provides users with useful information when selecting a method for future studies.

5. Conclusion

Selecting a supplier significantly impacts a company's operations in various aspects, including economics, customer satisfaction, production schedule, product quality, and the manufacturer's reputation and brand. This study applied four different methods to rank eight plastic resin suppliers for a Vietnamese plastic manufacturing company. Three of the four methods used are relatively new, including *RAM*, *OPARA*, and *MUTRISS*, while the other method, *TOPSIS*, has been widely used in supplier selection problems. The weights of the criteria for each supplier were also calculated using four different methods: the Equal Weights method, the Entropy method, the *MEREC* method, and the *SPC* method. Some conclusions can be drawn as follows:

- Regardless of the ranking method or weighting method used, *A1* and *A5* were consistently the preferred choices, while *A4* was consistently avoided.
- All four methods, *RAM*, *OPARA*, *MUTRISS*, and *TOPSIS*, were suitable for ranking plastic resin suppliers in this study.
- In terms of the effectiveness of ranking alternatives when the weights of the criteria change, *TOPSIS* performed best, followed by *OPARA* and *MUTRISS*, with *RAM* performing the least effectively.
- To achieve a more comprehensive ranking of plastic resin suppliers, it is necessary to consider additional factors, such as resin parameters, the properties of the finished plastic products, the supplier's reputation, and the opinions of experts regarding the importance of the criteria. These aspects should be addressed in future studies.

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