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Integrated Analytic Hierarchy Process and Preference Ranking Organization Method for Enrichment Evaluation II for Supplier Selection

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Abstract. Supplier selection serves as the most critical factor in the supply chain, which involves several criteria. The selection of the right supplier supports the company's competition. To support the right decision-making, a credible and practical decision-making method is thus required. This study aims to integrate the Analytic Hierarchy Process (AHP) and PROMETHEE II methods for supplier selection. In utilizing this method, AHP is utilized to determine the weight of each criterion, and PROMETHEE II is employed to determine supplier ranking. The case study was conducted in the wood processing industry, involving the ten criteria applied in supplier selection. Furthermore, the three suppliers are ranked according to the PROMETHEE II method, indicating that A1 is ranked first with a net flow value of 0.1850.

INTRODUCTION

Suppliers are business partners who play an essential role in ensuring the availability of goods required by the company [1] [2]. Therefore, the selection of the proper supplier affects the success of a manufacturing company [3]. Supplier selection is how a company identifies, evaluates, and contracts with suppliers [4]. Therefore, choosing the right supplier helps reduce purchasing costs and enhances company competitiveness [5] [6]. In the traditional method, supplier selection is solely based on the lowest price criteria. However, upon considering the cost, several arising problems are inevitable due to the company's decision. For example, the quality of raw materials is not utilized as an indicator in the selection of suppliers, in which raw materials were below the standard. Furthermore, suppliers' delivery delays are also not employed as an indicator in supplier selection, compromising the production activities.

Several methods are utilized to solve problems in supplier selection. Durmic utilizes the FUCOM method and the Rough SAW model for supplier selection to achieve sustainability [7]. Haeri employs the best-worst method and fuzzy cognitive maps for supplier selection that combines economic and environmental criteria [8]. Badi uses the Grey-MARCOS method for supplier selection to iron and steel companies [9]. Cavalcante utilizes simulation techniques and machine learning to navigate the best suppliers in digital manufacturing [10]. Kannan combines the best-worst fuzzy method and the VIKOR interval to evaluate and prioritize suppliers [11].

There are several methods utilized to solve problems in supplier selection. However, studies related to supplier selection using the AHP and PROMETHEE II methods have been inadequate. This study attempts to propose the AHP and PROMETHEE II procedures for the AHP and PROMETHEE II methods, frequently navigated in fields such as 3PL selection, such as: [12], selection of deputy candidates for nomination [13], machine tool selection [14], evaluation of solar power plant location alternatives [15], and selection of Training Participants[16]. In addition, the AHP method has been widely utilized to address MCDM problems [17, 18]. However, the conventional AHP method cannot overcome the uncertainty and ambiguity of a person to the exact number or ratio. Therefore, the AHP method is recognized as a practical approach [19]. Furthermore, the PROMETHEE II method is a ranking method that is relatively simple in terms of concept and application compared to other methods for multi-criteria analysis [20]. In this study, the Analytical Hierarchy Process was utilized to resolve the unstructured criteria into a hierarchical form and weighted each criterion. Furthermore, the latter is utilized as input for supplier ranking with PROMETHEE II.

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METHODS

This section describes the stages of the Analytical Hierarchy Process (AHP) and PROMETHEE II procedures in supplier selection. The Analytical Hierarchy Process (AHP) was initially developed by Thomas L. Saaty [21]. The Analytical Hierarchy Process (AHP) is designed to solve complex problems, indicating that the criteria for a problem are many (multi-criteria), and the problem structure is unclear. Therefore, AHP was elected to choose the best alternative evaluated with related criteria.

AHP steps and procedures in solving problems are as follows: (1) Defining the problem and the desired solution, in setting priorities, the problem of prioritization is decomposed into the goals (goals) of an activity, identification of options (alternatives), and formulation of criteria for selecting priorities; (2) Developing the hierarchy initiated with the primary goal. According to Saaty [21], hierarchy is defined as representing a complex problem in a multi-level structure where the first level includes the goal, followed by the level of factors, criteria, sub-criteria, and up to down last level of alternatives.

Step (3) contains the assessment of the priority elements of the criteria and alternatives. At this stage, the assessment is based on pairwise comparisons between criteria. A scale of 1 to 9 is utilized to express the opinion of an expert. Step (4) is conducted to create a paired matrix. For each criterion and alternative, the pairwise comparison compares each element with other elements at each hierarchy level in pairs. Thus the value of the importance of the elements in the form of a qualitative opinion is obtained.

Step (5) is conducted to calculate the value of the normalized matrix and the weighting value. The calculation of the normalized matrix value is based on Equation 1. Furthermore, the weighted value is based on Equation 2, in which, a_{ij} is the row normalization matrix, and W_{ij} is the weighting value. Step 6 is to calculate the eigenvector value, consistency index and consistency ratio. The eigenvector calculation is based on Equation 3. Furthermore, the calculation of consistency index and consistency ratio is based on Equation 4 and Equation 5, in which λ max denotes the maximum eigenvector, and CI is the index consistency. The consistency ratio is denoted by CR, and RI indicate the random index. . n is as the number of criteria.

The last step of AHP is to test the consistency value, in accordance with the study of Saaty explained that there was an inconsistency when filling out the criteria weights, thus Saaty defined a consistency ratio to provide a consistent tolerance matrix criteria. The matrix is considered consistent if CR<0.1 or inconsistency is allowed to reach 0% according to Rodriguez [22]. The results of the AHP calculation is utilized to determine the priority criteria based on the highest weighted score.

$$a_{ij} = \frac{a_{ij}}{\max a_{ij}} \tag{1}$$

$$W_{ij} = \frac{\sum_i a_{ij}}{n} \tag{2}$$

$$\lambda \max = \frac{\sum a_{ij}}{\mathrm{n}} \tag{3}$$

$$\mathrm{CI} = \frac{(\lambda \max - n)}{(\mathrm{n} - 1)} \tag{4}$$

$$\mathrm{CR} = \frac{CI}{\mathrm{RI}} \tag{5}$$

After the weight of the criteria is calculated, the next step is the ranking of suppliers based on the PROMETHEE II method, as one of the methods for solving multi-criteria problems developed by JP Brans in 1982. The PROMETHEE II principle is to be conducted to utilize the principle of the value of the relationship between outranking [23]. PROMETHEE II is developing the PROMETHEE II method by considering the net flow value in the ranking process. This method has four main steps. Step (1) is to normalize the decision matrix. The decision matrix is based on the supplier's assessment on each criterion. Decision matrix normalization is utilized since the assessment of each criterion has a different scale. This normalization produces a new value with the same scale, including a minimum value of 0 (zero) and a maximum of 1 (one). This procedure is presented in Equation 6 and

Equation 7. Equation 6 is utilized to normalize the criteria for higher value is better (benefit), and Equation 7 is utilized to normalize the criteria for lower value (cost).

$$r_{ij} = \frac{[x_{ij} - \min(x_{ij})]}{[\max(x_{ij}) - \min(x_{ij})\}} \quad (6)$$

$$r_{ij} = \frac{[\max(x_{ij}) - x_{ij}]}{[\max(x_{ij)} - \min(x_{ij})\}} \quad (7)$$

Step (2) contains the determination of the preference function. PROMETHEE II has 6 (six) types/preference types[23]: Type I (usual criterion), Type II (quasi criterion), Type III (linear criterion), Type IV (level criterion), Type V (linear area criterion), Type VI (Gaussian criterion). The type of preference determines each criterion. Stage (3) contains the calculation of the multi-criteria preference index, determined based on the average weight of the preference function presented in Equation 8, in which φ represents the preference index, π presents the weight, and P indicate the preference function. The final step includes rank using the PROMETHEE II. It based on the net flow value Equation 11, difference Leaving flow Equation 9 and Entering flow Equation 10.

$$\varphi(a,b) = \sum_{i=1}^{n} \pi P_i(a,b); \forall a,b \in A \quad (8)$$

$$\emptyset^+(a) = \frac{1}{n-1} \sum \varphi(a,x) x \in A \quad (9)$$

$$\emptyset^-(a) = \frac{1}{n-1} \sum \varphi(x,a) x \in A \quad (10)$$

$$\emptyset(a) = \emptyset^+(a) - \emptyset^-(a) \quad (11)$$

This study is regarded as a case study on a wood processing industry located in Indonesia. The 10 criteria used in this research are illustrated in Table 1. The selected company has 3 suppliers that supply goods. This problem hierarchy which explains the objectives, criteria and alternatives, is illustrated in Figure 1. The purpose of this AHP calculation is to determine the weight of the criteria for supplier selection. The respondents of this research include the wood processing industry procurement manager.

TABLE 1. Supplier criteria list

No	Criteria	Description
1.	Conformance of specifications (C1)	Assessing the raw materials are in accordance with the standards desired by the company.
2.	Consistent quality (C2)	Assessing the quality of the delivered materials is the same with every purchase [24].
3.	Price (C3)	Assessing the price of products offered by suppliers [24]
4.	Payment system (C4)	Assessing the length of the payment grace period.
5.	Discount (C5)	Providing a discount on the goods for the suppliers [25]
6.	Lack of raw materials (C6)	Assessing the amount of raw materials provided by the supplier in accordance with the quantity ordered [26]
7.	Shipping (C7)	Timeliness in ordering [24].
8.	Distance (C8)	The distance from the supplier to the company is large.
9.	Ease of contact (C9)	Suppliers are easy to contact when there is a request v
10.	Replacement of damaged goods (C10)	Replacing the supplier when finding the damaged goods [26]

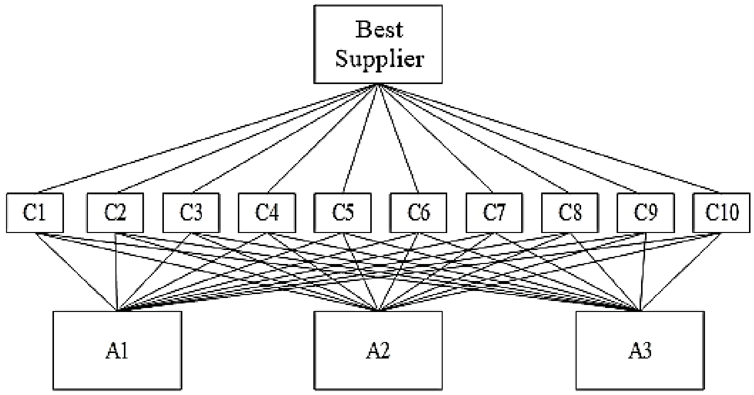

FIGURE 1. Hierarchy of supplier selection

RESULTS AND DISCUSSION

The results of the pairwise comparison matrix are illustrated in Table. 2, utilized to determine the weight of each criterion. The results of normalization to the calculation of the normalization matrix value and the weighting value are illustrated in Table 3, indicating that the price criterion (C3) obtains the largest weight of 0.22. Product price serves as one of the biggest contributors to the company's operating costs. Therefore, price has a high level of importance compared to other criteria. Furthermore, the discount criteria (C5), ease of contact (C9), and replacement of damaged goods (10) produce the lowest weight of 0.03. Furthermore, the calculation of the inconsistency is conducted, indicating the result of 0.07, concluded that the data is consistent because the value is <0.1.

TABLE 2. Pairwise Matrix

Criteria	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
C1	1.00	3.00	1.00	5.00	3.00	3.00	3.00	3.00	5.00	5.00
C2	0.33	1.00	0.33	3.00	5.00	3.00	0.33	1.00	5.00	5.00
C3	1.00	3.00	1.00	5.00	5.00	3.00	3.00	5.00	5.00	5.00
C4	0.20	0.33	0.20	1.00	3.00	0.20	0.20	1.00	3.00	3.00
C5	0.20	0.20	0.20	0.33	1.00	0.33	0.20	0.33	1.00	1.00
C6	0.33	0.33	0.33	5.00	3.00	1.00	0.33	3.00	3.00	3.00
C7	0.33	3.00	0.33	5.00	5.00	3.00	1.00	3.00	5.00	5.00
C8	0.20	0.20	0.33	5.00	3.00	0.33	0.33	1.00	3.00	3.00
C9	0.20	0.20	0.20	0.33	1.00	0.33	0.20	0.33	1.00	1.00
C10	0.20	0.20	0.20	0.33	1.00	0.33	0.20	0.33	1.00	1.00
Total	3.99	11.47	4.12	30.00	30.00	14.53	8.80	18.00	32.00	32.00

TABLE 3. Pairwise Matrix Normalization and weighting results

Criteria	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	Amount	Weight
C1	0.25	0.26	0.24	0.17	0.10	0.21	0.34	0.17	0.16	0.16	2.05	0.20
C2	0.08	0.09	0.08	0.10	0.17	0.21	0.04	0.06	0.16	0.16	1.13	0.11
C3	0.25	0.26	0.24	0.17	0.17	0.21	0.34	0.28	0.16	0.16	2.23	0.22
C4	0.05	0.03	0.05	0.03	0.10	0.01	0.02	0.06	0.09	0.09	0.54	0.05
C5	0.05	0.02	0.05	0.01	0.03	0.02	0.02	0.02	0.03	0.03	0.29	0.03
C6	0.08	0.03	0.08	0.17	0.10	0.07	0.04	0.17	0.09	0.09	0.92	0.09
C7	0.08	0.26	0.08	0.17	0.17	0.21	0.11	0.17	0.16	0.16	1.56	0.16
C8	0.05	0.02	0.08	0.17	0.10	0.02	0.04	0.06	0.09	0.09	0.72	0.07
C9	0.05	0.02	0.05	0.01	0.03	0.02	0.02	0.02	0.03	0.03	0.29	0.03
C10	0.05	0.02	0.05	0.01	0.03	0.02	0.02	0.02	0.03	0.03	0.29	0.03
							Total					1

This study utilizes the two types of preferences, of the usual and the V-shape. The usual preference type is utilized for qualitative data such as C1, C2, C4, C9, and C10. Another C7 also utilized the usual type since the difference is insignificant. Meanwhile, quantitative data such as C3, C5, C6, and C8 use the V-shape preference type. The data and preference types are illustrated in Table 4 in which the results of the PROMETHEE II calculation are illustrated in Table 5.

TABLE 4. Preference data and types

Code	Alternative			Aim	Preferen ce Type
	A1	A2	A3		
C1	5	4	4	*Max*	*Usual*
C2	4	3	3	*Max*	*Usual*
C3	IDR. 650,000	IDR. 430,000	IDR. 500,000	*Min*	*V-shape*
C4	4	2	3	*Max*	*Usual*
C5	7%	0%	10%	*Min*	*V-shape*
C6	4.8 m3	11.36 m3	7.5 m3	*Min*	*V-shape*
C7	3 days	1 day	5 days	*Min*	*Usual*
C8	72 Km	31 Km	58 Km	*Min*	*V-shape*
C9	5	3	4	*Max*	*Usual*
C10	4	2	1	*Max*	*Usual*

TABLE 5. PROMETHEE II Calculation Results

Alternative	*Leaving*	*Entering*	*Net Flow*	Order
A1	0.5050	0.3200	0.185	1
A2	0.3804	0.4144	-0.034	2
A3	0.2459	0.3969	-0.151	3

A higher net flow value indicates that the supplier has priority to choose. The research results indicate that the best supplier is supplier A1 with a value of 0.185. The second position is supplier A2 with a value of -0.0340, and the last position is supplier A3 with a value of -0.1510. The reason alternative A1 obtains the first place is that it excels in several criteria, such as Conformance of specifications (C1), Consistent quality (C2), Payment system (C4), Accuracy of raw materials (C6), Ease of contact (C9), and Replacement of damaged goods (C10). Meanwhile, alternative A3 obtains the last order because it does not excel in all aspects of the criteria.

CONCLUSIONS

This study attempts to utilize the AHP and PROMETHEE II methods in selecting the best supplier. The case study was conducted on the wood processing industry in Indonesia. The three alternative suppliers are ranked based on ten criteria. The results of the weighting with AHP indicate that the Conformity Specification presents a weight of 0.20. Consistent Quality presents a weight of 0.11, and Price presents a weight of 0.22. The Payment System denotes a weight of 0.05, and the Discount denotes a weight of 0.03. The criteria for lack of raw materials have a weight of 0.09, and on-time delivery results in a weight of 0.16. The criteria for Distance have a weight of 0.07, Ease of contact, and Replacement of damaged goods both obtain a weight of 0.03. The results of supplier ranking using PROMETHEE II indicate supplier A1 as the first rank with a net flow value of 0.185, followed by supplier A2 with a net flow value of -0.034, and the third rank indicates supplier A3 with a net flow value of -0.151.

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