Integration of Rough SWARA and COPRAS in the Performance Evaluation of Third-Party Logistics Providers

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ABSTRACT

Currently, the use of logistics service providers in companies has become a decision chosen by several companies. Companies use Third Party Logistics (3PL) to focus more on other essential activities in the company. Evaluating the performance of a 3PL provider is an essential process in determining the performance of a 3PL provider. A wrong evaluation process could lead to company's loss. The main objective of this study was to propose a 3PL performance appraisal procedure. This study integrated the Rough method Step-wise Weight Assessment Ratio Analysis (SWARA) and the Complex Proportional Assessment Method (COPRAS) to assess the performance of 3PL providers. The SWARA Rough method was used to assess the ranking of the criteria. The results of the Rough SWARA ranking were utilized by the COPRAS method to assess supplier performance. A case study was conducted in an animal feed production company in Indonesia. The results showed that there were criteria for product safety; on-time delivery, responsiveness, and flexibility with the greatest weight among the 16 criteria used.

1. Introduction

The global market growth that is getting faster worldwide has resulted in an increasing logistics function [1]. It causes the supply chain problem to become more complex because it involves transportation and distribution arrangements [2]. Transportation is one of the dominant logistical activities in the supply chain. This activity accounts for a significant total operational cost [3] [4]. The company's logistics system implements several strategies to minimize costs, including using their vehicle, hiring a 3PL provider, and using both options depending on relevant needs [5]. The use of logistics provider services (3PL) in companies is currently a decision that is often used by companies [6] [7] [8]. 3PL provider performance evaluation is a crucial evaluation process in supply chain management [9]. The provider performance evaluation process is used to measure performance and determine follow-up on necessary things [10]. This activity is used to ensure customer needs have been met.

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According to Manotas-Duque, et al. [11], 3PL service providers are external companies that manage, control, and support logistics activities. The 3PL provider performance evaluation process needs to determine the criteria needed to suit the company's problem conditions. Several studies were carried out on this problem, as expressed by Yeung [12]. His research evaluated 72 exporters in Hong Kong using four criteria: timeliness of service, price, quality of delivery, and additional services. The same research was also conducted by Mardani and Saptadi [13]. From the two studies above, the performance evaluation of 3PL providers is considered critical in logistics. The 3PL provider performance evaluation begins with identifying criteria by the company's conditions.

Apart from these two studies, several Multi-Criteria Decision Making (MCDM) approaches related to 3PL have been proposed. Some of the proposed procedures include Analytic Network Process, Analytic Hierarchy Process AHP [14] [15], Fuzzy AHP [16], and Simulation. Several integration methods were also proposed to solve this problem, including AHP and technique for order preference by similarity ideal solution (TOPSIS) [17], AHP and Goal Programming [18], AHP-ELECTRE I [19], Fuzzy AHP-Fuzzy Topsis [20], and Step-wise Weight Assessment Ratio Analysis (SWARA) - Weighted Aggregated Sum-Product Assessment method [21]. Many researchers offer new integration methods because they are considered to have many advantages compared to using a single method.

In previous studies, the weighting of criteria generally used AHP pairwise comparisons. This approach requires a high level of subjectivity in weighting. To reduce this problem, the Rough SWARA approach is proposed to weigh the 3PL provider performance evaluation criteria. The Rough SWARA method and the Complex Proportional Assessment (COPRAS) have not solved the 3PL evaluation problem. The Rough SWARA method was proposed by Zavadskas, et al. [22], which was used for weighting criteria. This method has the advantage of being able to evaluate the ideas of experts and estimate the ratio of relevant interests with the help of rough numbers. This method is used to reduce subjectivity and uncertainty in assessing criteria. Furthermore, the COPRAS method [23] ranks alternative 3PL providers based on their significance and utility level. The contribution of this research is to provide an alternative approach in evaluating the performance of 3PL providers with the Rough SWARA and COPRAS methods.

This paper's structure is presented as follows: Section 2 presents the proposed method of SWARA-COPRAS rough integration and data and case studies. The results of weighting the criteria and performance evaluation of 3PL providers are presented in section 3. Meanwhile, section 4 discusses the conclusions of the research and suggestions for future work.

2. Methods

2.1 Proposed Method

This section presents a proposed procedure for evaluating the performance of 3PL providers. This study used Rough SWARA developed by Zavadskas, et al. [22]. The SWARA method allows assessing the opinions of experts on the significance of the criteria and sub-criteria. Many publications have discussed applying an integrated model that involves applying the multi-criteria decision-making method and the rough theory in recent years. Zavadskas, et al. [22] proposed the use of rough theory in order to reduce subjectivity. Furthermore, the COPRAS method is one of the MCDM methods. This method selects the best alternative by considering the positive ideal solution, the negative ideal solution, and the significance of the alternatives considered. This method was

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developed by Zavadskas and Kaklauskas [23] in evaluating 3PL providers and selecting alternative 3PL providers. The proposed method framework can be seen in Fig. 1.

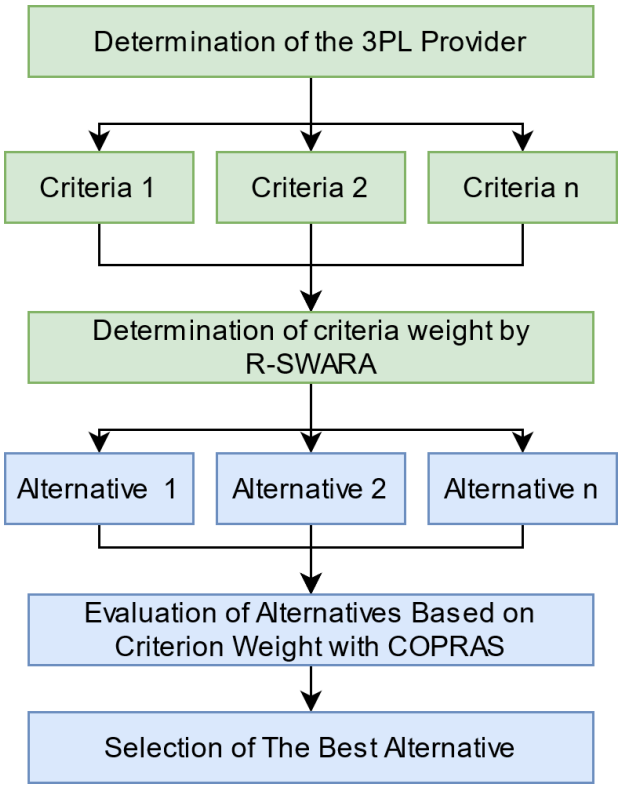

Fig. 1. A framework of R-SWARA and COPRAS methods

Based on the R-SWARA and COPRAS Method Framework in Fig. 1, the detailed steps that need to be taken to solve the 3PL provider performance evaluation problem are as follows:

Step (1) is to establish a set of criteria in evaluating the performance of the 3PL provider. After the 3PL provider, performance evaluation criteria are determined. Step (2) is that the decision-maker needs to rank the criteria based on priority. The decision maker's ranking criteria are converted into a rough matrix group (Step (3)). The conversion formula can be presented in equation (1) to equation (6).

$$\underline{Apr}(G_q) = \{Y \in U \,/\, R(Y) \leq G_q\}, \tag{1}$$

$$\overline{Apr}(G_q) = \{Y \in U \,/\, R(Y) \geq G_q\}, \tag{2}$$

$$\begin{aligned}\overline{Bnd}(G_q) &= \{Y \in U \,/\, R(Y) \neq G_q\} \\ &= \{Y \in U \,/\, R(Y) > G_q\} \cup \{Y \in U \,/\, R(Y) < G_q\}\end{aligned} \tag{3}$$

$$\underline{Lim}(G_q) = \frac{1}{M_L} \sum R(Y) \,|Y \in \underline{Apr}(G_q) \tag{4}$$

$$\overline{Lim}(G_q) = \frac{1}{M_U} \sum R(Y) \,|Y \in \overline{Apr}(G_q) \tag{5}$$

$$RN(G_q) = [\underline{Lim}(G_q), \overline{Lim}(G_q)] \tag{6}$$

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Step (4) is to normalize the matrix RN (cj) to get the matrix RN (sj). The criteria that are in the first position have a value of 1. Meanwhile, other criteria can be calculated in equation (7). Step (5) is to calculate the matrix (kj). The criteria that are in the first position still have a value of 1, while other criteria can be calculated using equation (8). Step (6) is to determine the weight matrix. The criterion that is in the first position is still worth 1, while other sub-criteria can be calculated using equation (9).

$$RN(S_j) = \frac{\left[c_j^L, c_j^u\right]}{max\left[c_j^L, c_j^u\right]} \tag{7}$$

$$RN(K_j) = \left[s_j^L + 1, s_j^U + 1\right]_{1xm} j = 2,3,\dots,m \tag{8}$$

$$RN(Q_j) = \left[q_j^L = \begin{cases} 1.00\ j = 1 \\ \frac{q_{j-1}^L}{k_j^U}\ j > 1 \end{cases}, q_j^U = \begin{cases} 1.00\ j = 1 \\ \frac{q_{j-1}^U}{k_j^L}\ j > 1 \end{cases}\right] \tag{9}$$

Step (7) is to calculate the matrix at the relative weight value RN (Wj) presented in equation (10). Furthermore, Step (8) is normalizing the relative weight values RN (WjU) and RN (WjL) to become the relative weights RN (Wj) by taking the average of the two values.

$$\left[w_j^L, w_j^U\right] = \left[\frac{\left[q_j^L, q_j^U\right]}{\sum_{j=1}^{m}\left[q_j^L, q_j^U\right]}\right] \tag{10}$$

Step (9) is the decision-maker to assess the 3PL provider. The decision-maker gives the provider rating with a value scale of 0-100. The assessment results for each provider are constructed in a matrix as shown in equation (11). i denotes criteria, and j denotes alternatives. In addition, n is the number of criteria, and j is the number of alternative providers.

$$X = \begin{bmatrix} X_{11}\ X_{12} - - X_{1j} \\ X_{21}\ X_{22} - - X_{2j} \\ X_{31}\ X_{32} - - X_{3j} \\ - \quad - \quad - \quad - \quad - \\ X_{i1}\ X_{i2} - - X_{ij} \end{bmatrix}; i = 1,2,\dots,n \text{ and } j = 1,2,\dots,m \tag{11}$$

Step (10) is to normalize the decision matrix X. The decision normalization formula is presented in equation (12). Step (11) calculates the normalized weight of the decision-making matrix based on equation (13). Step (12) is to calculate the positive ideal solution (Si +) at the criterion value based on equation (14).

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$$\bar{X}_{ij} = \frac{X_{ij}}{\sum_{j=1}^{n} X_{ij}}; i = 1,2,\dots,n \text{ dan } j = 1,2,\dots,m \quad (12)$$

$$\hat{X}_{ij} = \bar{X}_{ij}\ x\ w_j\ ; i = 1,2,..,n\ dan\ j = 1,2,\dots,m \quad (13)$$

$$S_{i+} = \sum_{j=1}^{k} \hat{X}_{ij}\ ; j = 1,2,\dots,k \quad (14)$$

Step (13) is to calculate the ideal negative solution ($Si-$) presented in equation (15). Stage (14) is to calculate the relative significance or weight of the relative importance of each alternative Qi presented in equation (16). Step (15) is to determine alternatives based on the value of relative importance. The formula for determining the value of importance is presented in equation (17). The final step is to determine the performance index calculated based on equation (18).

$$S_{i-} = \sum_{j=k+1}^{m} \hat{X}_{ij}\ ; j = k+1, k+2, \dots, n \quad (15)$$

$$Q_i = S_{i+} + \frac{\sum_{i=1}^{n} S_i-}{S_{i-}\ x\ \sum_{i=1}^{n} \frac{1}{S_{i-}}} \quad (16)$$

$$K = \max\{Q_i\}, i = 1,2,\dots,m \quad (17)$$

$$N_i = \frac{Q_i}{Q_{max}}\ x\ 100\% \quad (18)$$

2.2 Case Study

A case study was applied to the largest animal feed company in Indonesia. This study evaluated the providers of raw material shipments from abroad. Three (3) respondents as the decision-makers in this study were the General Manager, Senior Manager, and Supervisor of the import division. Four (4) providers were evaluated in this case study.

The identification of aspects and criteria was based on the results of previous studies conducted by Aguezzoul [24], Hajar and Arifin [16], Bulgurcu and Nakiboglu [25], and Mardani and Saptadi [13], resulting in several criteria in evaluating the performance of 3PL providers. Furthermore, the decision-makers brainstormed the ideas to determine the aspects and criteria used. Six aspects and 16 criteria were successfully collected in assessing 3PL performance. The aspects and criteria used can be seen in Table 1.

Three decision-makers (DM) ranked the criteria and assessed the 3PL provider. The ranking results for each criterion are presented in Table 2. Furthermore, the average 3PL provider rating results from each criterion's decision-makers are presented in Table 3.

3. Results and Discussion

3.1 Weights of 3PL provider evaluation criteria

Fig. 2 shows the results of the weighted criteria. Security and safety criteria (C9) was a criterion that has the highest weight value of 0.336. The second and third positions were the criteria for Punctuality (C8) and Responsiveness and Flexibility (C7). Timelines have a weight of 0.245, and Responsive and Flexible criteria have a weight of 0.178.

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Furthermore, the criteria for the duration of invoice submission (C3) was the criterion with the lowest value, amounting to 0.001. These results indicated that the company paid attention to security and safety aspects in the product delivery process.

Table 1. 3PL provider evaluation aspects and criteria

Aspect	Criteria	Code	Decision	Remark
Financial Performance	Payment System	C1	Max	Ease of Payment
	Financial Stability	C2	Max	Measurement of provider's financial condition and balance of providers' income
Billing and Payment Flexibility	The length of time for submitting invoices	C3	Min	Invoice submission is not delayed
	Document accuracy	C4	Max	Completeness of documents that can be accounted for
	Price Match	C5	Max	The value match between the agreed price and what is written on the invoice
Service Level	Guarantee Policy	C6	Max	Policy in providing guarantees if something goes wrong
	Responsive and Flexible	C7	Max	Responsive and able to adapt to circumstances
	Punctuality	C8	Min	The logistic process do not experience any delays
Operational	Security and Safety	C9	Max	Product safety and security to the destination
	Optimization Capabilities	C10	Max	Ability to optimize routes, schedules, and facilities
	Fleet Availability	C11	Max	Availability of a fixed number of fleets and types of fleets
Information Technology	Information Technology	C12	Max	Ease of tracking goods (GPS)
	Information Sharing	C13	Max	Ease of providing information related to delivery, communication, and coordination between the two parties
Intangible	Long Term Relationship	C14	Max	Cooperation between the two parties and being able to share risks and rewards to control the opportunistic behavior of providers
	Reputation	C15	Max	Customer opinion regarding how well the provider is in meeting their needs
	Experience	C16	Max	Providers demonstrate good service knowledge and the way they interact and present to customers

3.2 3PL provider evaluation

From the weighted results, the 3PL provider evaluation was carried out in several stages, such as normalizing the decision matrix, determining the decision weight matrix, determining the useful criteria and useless criteria, and calculating the positive ideal solution and the negative ideal solution. Furthermore, these results can be seen in Table 4 to Table 7.

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The decision weight matrix Table 5 was based on the multiplication of each value in the decision normalization matrix in each element Table 4 with the weight of each criterion that has been determined using the Rough SWARA method. Table 6 portrays the useful and useless criteria classification where the division was based on whether the criteria were maximum or minimum. The useful criteria were C1, C2, C4, C5, C6, C7, C9, C10, C11, C12, C13, C14, C15, and C16. Meanwhile, the useless criteria were C3 and C8.

Table 7 pictures the results of the positive and negative ideal solutions for each provider. For a positive ideal solution, it was obtained from the sum of the decision weights in the useful criteria, while for the negative ideal solution, it was obtained from the sum of the decision weights on the useless criteria for each provider. Meanwhile, for determining provider preference, the relative importance weight (Qi) was used as the basis for determining the performance index (Ni) for each provider. The results suggested that Provider A was in rank 1, Provider B was in rank 2, Provider C was in rank 4, and Provider D was in rank 3. The performance index value of each provider can be found in Fig. 3.

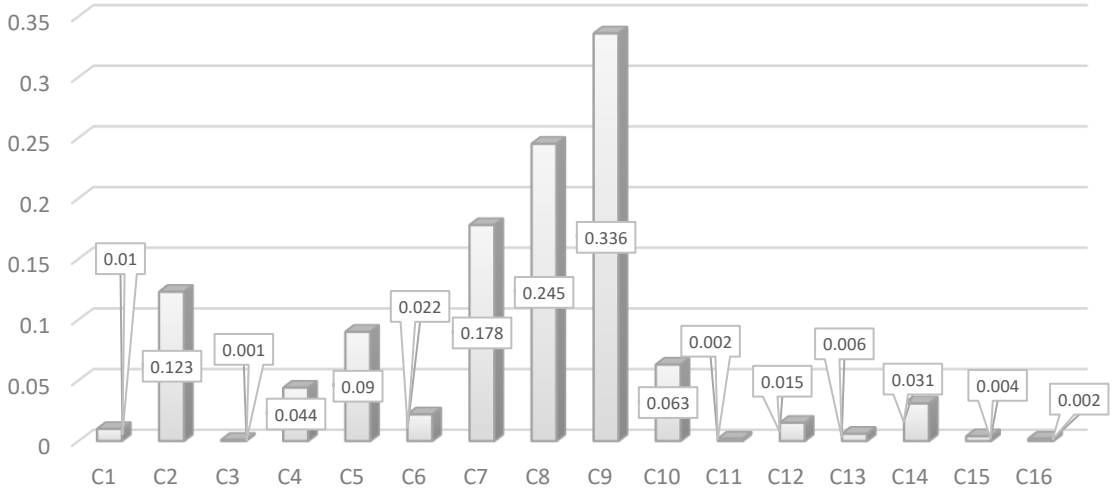

Fig. 2. Criteria Weights

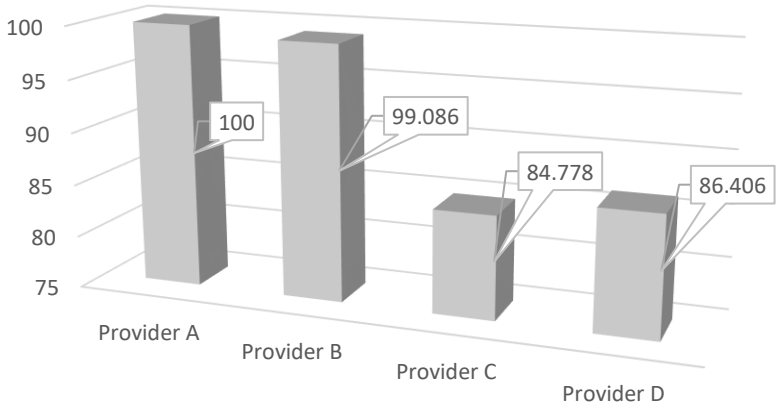

Fig. 3. Performance Index Value

Table 2. Ranking of criteria and sub-criteria

Criteria	Criteria Ranking		
	DM1	DM2	DM3
C1	4	14	12
C2	3	15	6
C3	16	10	15
C4	6	4	14
C5	5	7	5
C6	15	2	11
C7	7	6	4
C8	1	16	2
C9	2	3	1
C10	8	13	3
C11	9	9	16
C12	10	5	10
C13	11	8	9
C14	14	1	13
C15	12	11	7
C16	13	12	8

Table 3. 3PL provider assessment on each criterion by decision

Criteria	Decision	Provider			
		A	B	C	D
C1	Max	91	90	72	70
C2	Max	90	88	72	71
C3	Min	82	85	72	74
C4	Max	80	79	70	74
C5	Max	92	89	70	74
C6	Max	85	80	70	71
C7	Max	87	88	65	68
C8	Min	90	90	66	68
C9	Max	94	92	65	68
C10	Max	88	91	69	73
C11	Max	98	95	57	61
C12	Max	91	91	69	70
C13	Max	89	88	74	70
C14	Max	90	92	70	72
C15	Max	90	92	52	56
C16	Max	90	90	67	70

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Table 4. Normalization of the Decision Matrix

Criteria	Min/Max	weight	Provider A	Provider B	Provider C	Provider D
C1	Max	0.010	0.282	0.279	0.223	0.217
C2	Max	0.123	0.280	0.274	0.224	0.221
C3	Min	0.001	0.262	0.272	0.230	0.236
C4	Max	0.044	0.264	0.261	0.231	0.244
C5	Max	0.090	0.283	0.274	0.215	0.228
C6	Max	0.022	0.278	0.261	0.229	0.232
C7	Max	0.178	0.282	0.286	0.211	0.221
C8	Min	0.245	0.287	0.287	0.210	0.217
C9	Max	0.336	0.295	0.288	0.204	0.213
C10	Max	0.063	0.274	0.283	0.215	0.227
C11	Max	0.001	0.315	0.305	0.183	0.196
C12	Max	0.015	0.283	0.283	0.215	0.218
C13	Max	0.006	0.277	0.274	0.231	0.218
C14	Max	0.031	0.278	0.284	0.216	0.222
C15	Max	0.004	0.310	0.317	0.179	0.193
C16	Max	0.002	0.284	0.284	0.211	0.221

Table 5. Decision Weight Matrix

Criteria	Min/Max	Provider A	Provider B	Provider C	Provider D
C1	Max	0.003	0.003	0.002	0.002
C2	Max	0.035	0.034	0.028	0.027
C3	Min	0	0	0	0
C4	Max	0.012	0.012	0.01	0.011
C5	Max	0.025	0.025	0.019	0.02
C6	Max	0.006	0.006	0.005	0.005
C7	Max	0.05	0.051	0.038	0.039
C8	Min	0.07	0.07	0.051	0.053
C9	Max	0.099	0.097	0.069	0.072
C10	Max	0.017	0.018	0.014	0.014
C11	Max	0	0	0	0
C12	Max	0.004	0.004	0.003	0.003
C13	Max	0.002	0.002	0.001	0.001
C14	Max	0.009	0.009	0.007	0.007
C15	Max	0.001	0.001	0.001	0.001
C16	Max	0.001	0.001	0	0.001

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Table 6. Useful and Useless Criteria Classification

Criteria		Min/Max	Provider A	Provider B	Provider C	Provider D
Useful	C1	Max	0.003	0.003	0.002	0.002
	C2	Max	0.035	0.034	0.028	0.027
	C4	Max	0.012	0.012	0.01	0.011
	C5	Max	0.025	0.025	0.019	0.02
	C6	Max	0.006	0.006	0.005	0.005
	C7	Max	0.05	0.051	0.038	0.039
	C9	Max	0.099	0.097	0.069	0.072
	C10	Max	0.017	0.018	0.014	0.014
	C11	Max	0	0	0	0
	C12	Max	0.004	0.004	0.003	0.003
	C13	Max	0.002	0.002	0.001	0.001
	C14	Max	0.009	0.009	0.007	0.007
	C15	Max	0.001	0.001	0.001	0.001
Useless	C16	Max	0.001	0.001	0	0.001
	C3	Min	0	0	0	0
	C8	Min	0.07	0.07	0.051	0.053

Table 7. Positive and Negative Ideal Solutions

Ideal Solution	Provider			
	A	B	C	D
Si+	0.264	0.261	0.197	0.204
Si-	0.070	0.070	0.052	0.053

4. Conclusion

The purpose of this study was to propose a Rough SWARA and COPRAS procedure in evaluating the performance of 3PL providers. This study observed six aspects with 16 criteria in evaluating the performance of 3PL providers. This study has succeeded in integrating Rough SWARA and COPRAS in the 3PL performance evaluation. The results indicated that product security and safety criteria were the criteria with the most significant weight, followed by the criteria for on-time delivery, responsiveness and flexibility, and financial stability. From the results of the 3PL provider performance evaluation, it showed that provider A had the highest performance index, followed by provider B, provider C, and provider D. These results can be used as a company reference for a description of providers that have a performance index that matches the company's wants and needs. This research can be further developed by considering sustainable aspects such as social, environmental, and economic aspects.

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