Analysis of coffee bean supplier selection using AHP-TOPSIS methods: case study on a ready-to-use coffee powder company

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ABSTRACT

The global market competition that companies must face along with increasingly competitive market developments means that each company has its own challenges in preparing competitive strategies. PT. XYZ is a company that operates in the field of coffee bean processing. The related problems that occur are frequent delays in sending raw materials by suppliers which results in delivery delays, which means they are related to supplier selection problems. Therefore, in this research, the AHP TOPSIS method was used to conduct supplier analysis, AHP is utilized to make decisions and consider multiple factors, subsequently ranking them. Meanwhile, TOPSIS is employed to address multi-criteria problems by comparing the best alternative with the worst alternative among many options. The results of this research are that Supplier 4 is in first place with a preference value of 0.6510, while the second and third places are occupied by Supplier 1 and Supplier 3 respectively.

1. Introduction

Technical advancements continually progressing and the current stringent business environment compel business idea owners to compete vigorously in producing high-quality products (Zahira & Pulansari, 2023). In this scenario, companies must be capable of sustaining and maintaining the continuity of the production process to avoid hindrances. The most crucial activity for companies in maintaining the production process is inventory management. One of the key activities in inventory management is ensuring the availability of high-quality raw materials (Hati & Fitri, 2017). According to Khairun Nisa et al. (2019), one way for a company to ensure the provision of high-quality raw materials is by selecting suppliers. The selection of raw material suppliers is a crucial component in supply chain management, where the short-term and long-term success of a company heavily relies on the selection of the right supplier. As mentioned by Talangkas & Pulansari (2021) this is because suppliers play a vital role in the availability of raw materials. Raw materials are needed for the company to smoothly carry out its production activities. Therefore, the selection of a supplier will impact the company's future processes from production to sales. If the supplier selection is not done properly, it can lead to an increase in production costs, production delays, substandard product quality, and so on. Hence, the company's risk of losses can be minimized by selecting suppliers carefully and accurately.

PT. XYZ is a company engaged in the processing of coffee beans into ready-to-use coffee powder. In its production process, good cooperation among all parties involved in the coffee supply chain is essential to produce the best coffee powder. Historically, the company has relied on several suppliers to provide the same raw materials needed. Recently, the company has encountered issues

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in the selection of coffee bean suppliers, particularly related to frequent delays in the delivery of raw materials by suppliers, resulting in delivery delays of 1-3 weeks. This issue is common among some of the company's suppliers, involving the processing of coffee cherries into ready-to-process coffee beans, which includes stages such as fruit skin peeling, fermentation, drying, husk peeling, packaging, quality control, and supervision. To maintain quality, the company has set criteria for selecting coffee beans, including the absence of live insects, no foul or moldy odor, a maximum moisture content of 12.5%, and a maximum non-coffee impurity content of 0.5%. The quality assessment significantly affects the produced coffee powder's quality, leading to coffee that does not meet the company's standards, resulting in the supplier's inability to deliver raw materials within the specified timeframe.

Concerning supplier selection, the AHP method is preferred. Several reasons support this choice, such as AHP providing a hierarchical representation of a problem that aids in decision-making. The TOPSIS method is used as a supporting tool, based on straightforward logic and relatively easy-to-understand calculation processes. The best alternative to choose is the one with the closest distance to the positive ideal solution and the farthest distance from the negative ideal solution.

Several previous studies have established criteria for selecting supplier raw materials. For instance, research conducted by Dickson (1966) as cited in (Tsai et al., 2021) listed 23 criteria for determining material suppliers, Fei outlined 14 criteria (Fei et al., 2019), and Chang identified 20 criteria (Chang et al., 2021). In several earlier studies, quality was considered the most important criterion, followed by delivery criteria. Using the Analytical Hierarchy Process (AHP), (Mahendra, 2019) weighed factors such as price, service, delivery speed, and availability. Subsequent research by (Sukma et al., 2022) utilized the TOPSIS method with tested criteria in the study, including attitude, price, warranty policy, accuracy of quantity, timeliness, material quality, geographical location, professional suppliers, delivery, and communication systems. Furthermore, research conducted by (Lukmandono et al., 2019), (Rochman et al., 2020),(Putri & Pulansari, 2022), (Sukendar et al., 2022), and (Nulsyah et al., 2022) employed the AHP and TOPSIS methods.

In contrast to previous studies, this research will employ a combination of AHP and TOPSIS methods to determine the quantitative and qualitative ranking of coffee bean suppliers, considering parameters such as quality, price, delivery, capacity, and warranty & service. The integration of the AHP-TOPSIS method is chosen to eliminate subjectivity from the use of a single AHP method (Putri & Pulansari, 2022).

2. Methods

This research utilizes primary data for analysis obtained from two questionnaires, which include the hierarchical levels of importance between criteria and sub-criteria and the evaluation of supplier performance. Respondents are employees of PT. XYZ directly involved in supplier selection. The researcher also conducted interviews with expert staff in the field who are actively engaged in the production process and the performance of raw material suppliers. Once the data is obtained, the researcher employs a combination of the AHP and TOPSIS methods for data processing.

The Analytical Hierarchy Process (AHP), commonly abbreviated as AHP, is a decision-making method involving multiple criteria that assigns rankings to available alternatives (Ramdani, 2018). AHP is a Multi-Criteria Decision Making (MCDM) method developed by Saaty in the 1990s, utilizing pairwise comparisons of criteria and sub-criteria for ranking purposes (Asadabadi et al., 2019)

The data processing in Analytical Hierarchy Process consists of the following steps:

a. Create a framework for the definition and analysis of the problem by compiling a list of objectives, criteria, sub-criteria, and current suppliers.
b. Create a paired comparison matrix and send it to the individual most familiar with the company's issues and situation. The objective of this comparison is to establish relative weights for various criteria and sub-criteria.
c. Multiply the eigenvalue vector used to determine consistency values by the normalized paired comparison matrix.
d. To move to the next level in the hierarchy, simply repeat steps 2 and 3.
e. To determine the maximum eigenvalue, divide the sum of each row by the total.
f. The validity of the collected information is examined through a consistency test. Researchers need to determine the number of criteria or sub-criteria used (n) to calculate the CI value. To pass the hierarchy consistency test, the CR value must be less than 0.1. The CR value is

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obtained from:

$$CR = CI/RI \quad (1)$$

$$CI = \frac{\lambda\, max - n}{n-1} \quad (2)$$

On the other hand, the TOPSIS method is one of the techniques that can be used to solve multicriteria problems. This method can provide solutions by comparing the distances between alternatives with the best and worst alternatives among the given alternatives (Setyaningsih, 2017).

The data processing in TOPSIS consists of the following steps:

a. Create a decision matrix using the responses from the questionnaire regarding supplier selection criteria.
b. Normalize the decision matrix by transforming each element

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{l=1}^{m} x_{ij}^2}} \quad (3)$$

c. Determine the weighted normalized decision matrix.

$$y_{ij} = w_i \times r_{ij} \quad (4)$$

d. Determining the Matrix of Positive Ideal Solution (A+) and Negative Ideal Solution (A-)

$$A^+ = y_1^+, y_2^+, \dots, y_n^+ \quad (5)$$

$$A^- = y_1^-, y_2^-, \dots, y_n^- \quad (6)$$

e. Determine the distance between alternative values.

$$Di^+ = \sqrt{\sum_{j=1}^{n} (y_i^+ - y_{ij})^2} \quad (7)$$

$$Di^- = \sqrt{\sum_{j=1}^{n} (y_{ij} - y_i^-)^2} \quad (8)$$

f. Determine the distance between the preference values of alternatives.

$$Vi = \frac{Di^-}{Di^- + Di^+} \quad (9)$$

3. Results and Discussion

In evaluating the determination of criteria and sub-criteria, the researcher conducted field studies and reviewed previous research on the criteria required in the supplier evaluation process (Table 1). The researcher also interviewed employees directly involved with suppliers to develop the criteria used for evaluation and to determine several sub-criteria based on references from other studies. The questionnaire was completed by employees directly involved with suppliers. In this study, two questionnaires are required.

The first questionnaire is utilized to determine the level of importance among criteria and sub-criteria, while the second questionnaire is employed to assess supplier performance. Both questionnaires are filled out by individuals responsible for supplier selection at PT. XYZ. The first questionnaire comprises paired comparison questions designed to ascertain the level of importance among the existing criteria. It employs a paired comparison questionnaire using a rating scale from 1 to 9. Each number reflects the relationship and level of importance between the compared criteria. On the other hand, the second questionnaire is designed to assess supplier performance. The rating scale used in this questionnaire ranges from 1 to 5, following the standard Likert scale.

3.1 Data Processing using AHP Method

Creating paired comparison matrices by summarizing responses from the respondents. The findings of supplier performance evaluation are presented in paired comparison matrices, one for each criterion as shown in Table 1. The next step involves constructing normalization matrices by dividing column elements by the total column value, as illustrated in Table 2. To test the consistency of these

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paired comparison matrices, multiply the columns by their respective rows, as demonstrated in Table 3. Calculating the share results is then necessary by dividing the eigenvalue of each criterion by the average of that criterion in the normalized results.

Table 1 Criteria and sub criteria for supplier selection

No	Criteria	Sub Criteria
1	Quality (Q)	Compliance with specifications (Q1)
		Consistency of quality (Q2)
2	Price (P)	Raw material price (P1)
		Shipping Costs (P2)
3	Delivery (D)	Coffee bean distribution capability (D1)
		On-time delivery (D2)
4	Capacity (C)	Agreement on the quantity of coffee bean orders (C1)
		Accuracy of the quantity of coffee beans delivered (C2)
5	Warranty and Service (W)	Speed of responding to complaint (W1)
		Providing warranty for raw materials (W2)

Table 2 Paired comparison matrix of criteria

Criteria	Quality	Price	Delivery	Capacity	Warranty
Quality	1	8	7	6	4
Price	1/8	1	2	1	2
Delivery	1/7	1/2	1	1/2	1
Capacity	1/6	1	2	1	3
Warranty	¼	1/2	1	1/3	1
Total	1.68	11	13	9	11

Table 3 Results of normalized criteria comparison matrix

Criteria	Quality	Price	Delivery	Capacity	Warranty
Quality	0.594	0.721	0.507	0.679	0.380
Price	0.074	0.093	0.184	0.132	0.143
Delivery	0.085	0.047	0.077	0.048	0.129
Capacity	0.099	0.093	0.155	0.106	0.262
Warranty	0.148	0.047	0.077	0.035	0.087
Total	1	1	1	1	1

The next stage involves calculating the maximum eigenvalue (λ max) from the data in Table 4.

$$\lambda \text{ max} = \frac{\Sigma(\frac{Wij}{\Sigma Wj})}{n}$$

$$\lambda \text{ max} = (5.749 + 5.496 + 5.235 + 5.287 + 5.196)/5$$

$$= 5.393$$

Once the value of λ max is known, the next step is to calculate the Consistency Index (CI), which is computed as follows:

$$\text{CI} = \frac{\lambda\, max - n}{n - 1}$$

$$\text{CI} = \frac{5.393 - 5}{5 - 1} = 0.098$$

From the above calculation, the Consistency Index (CI) is found to be 0.098. Once the Consistency Index is obtained, this value is used to calculate the Consistency Ratio (CR) with RI = 1.12, considering the matrix order is 5.

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$$CR = \frac{CI}{RI}$$

$$CR = \frac{0.098}{1.12} = 0,088$$

After calculating the Consistency Ratio (CR), the result indicates that CR < 0.1, which means it is consistent. The final weights assigned to each criterion and sub-criterion are presented in Table 4.

Table 4 Results of weighting criteria and sub criteria

Criteria	Weighting	Sub Criteria	Weighting
Quality (Q)	0.5761	Compliance with specifications	0.60
		Consistency of quality	0.40
Price (P)	0.1250	Raw material price	0.86
		Shipping Costs	0.14
Delivery (D)	0.0772	Coffee bean distribution capability	0.25
		On-time delivery	0.75
Capacity (C)	0.1428	Agreement on the quantity of coffee bean orders	0.74
		Accuracy of the quantity of coffee beans delivered	0.26
Warranty and Service (G)	0.0790	Speed of responding to complaint	0.29
		Providing warranty for raw materials	0.71

From Table 4, it can be observed that the weight values for the criteria are as follows: quality criteria is 0.5761, price criteria is 0.1250, delivery criteria is 0.0772, capacity criteria is 0.1428, and warranty and service criteria is 0.0790. Additionally, the weight values for sub-criteria are as follows: compliance with specifications is 0.60, consistency of quality is 0.40, raw material price is 0.86, shipping costs are 0.14, coffee bean distribution capability is 0.25, on-time delivery is 0.75, agreement on the quantity of coffee bean orders is 0.74, accuracy of the quantity of coffee beans delivered is 0.26, speed of responding to complaints is 0.29, and providing a warranty for raw materials is 0.71.

3.2 Data Processing using TOPSIS Method

The first step in processing data using the TOPSIS method is to create a decision matrix based on the questionnaire results to compare suppliers according to the predefined criteria and sub-criteria. Table 5 provides an overview of the evaluated potential suppliers. In the next step, the decision matrix is calculated by normalizing the decision using the m and n decision alternatives. Table 6 shows the results of the normalized decision matrix. Then, weighting is calculated by adjusting the rows and columns of the normalized decision matrix using the weights from the AHP method. Table 7 shows the matrix of weighted normalized decisions.

Table 5 Matrix of alternative supplier comparison

Coffee Bean Supplier for PT. XYZ	Quality		Price		Delivery		Capacity		Warranty	
	Q1	Q2	P1	P2	D1	D2	C1	C2	W1	W2
S1	4	5	5	5	4	5	4	4	5	5
S2	4	4	4	4	4	5	4	4	4	4
S3	4	4	5	5	4	5	4	4	4	5
S4	4	4	5	4	4	4	5	5	4	5
S5	4	4	4	3	4	5	4	4	4	4

Table 6 Normalized decision matrix

Coffee Bean Supplier for PT. XYZ	Quality		Price		Delivery		Capacity		Warranty	
	K1	K2	H1	H2	P1	P2	C1	C2	G1	G2

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S1	0.47	0.49	0.49	0.51	0.47	0.49	0.47	0.47	0.49	0.51
S2	0.45	0.45	0.45	0.40	0.45	0.49	0.47	0.47	0.45	0.47
S3	0.45	0.47	0.49	0.49	0.43	0.51	0.45	0.47	0.45	0.51
S4	0.45	0.47	0.49	0.47	0.47	0.47	0.49	0.49	0.47	0.51
S5	0.43	0.43	0.47	0.36	0.47	0.49	0.47	0.43	0.40	0.43

The weighted normalized matrix is obtained by multiplying each column of the normalized decision matrix by the corresponding weight. Thus, the results can be seen in the Table 7.

Table 7 Matrix from weighting of normalized decision matrix

Coffee Bean Supplier for PT. XYZ	Quality		Price		Delivery		Capacity		Warranty	
	K1	K2	H1	H2	P1	P2	C1	C2	G1	G2
S1	0.28	0.19	0.42	0.07	0.12	0.37	0.35	0.12	0.14	0.36
S2	0.27	0.18	0.38	0.06	0.11	0.37	0.35	0.12	0.13	0.33
S3	0.27	0.19	0.42	0.07	0.11	0.38	0.33	0.12	0.13	0.36
S4	0.27	0.19	0.42	0.07	0.12	0.35	0.36	0.13	0.13	0.36
S5	0.26	0.17	0.40	0.05	0.12	0.37	0.35	0.11	0.12	0.30

To determine the positive and negative ideal solutions, Table 8 displays these solutions, sorted based on sub-criteria. Next, calculate the distance values of each alternative by comparing their relative proximity to the positive and negative ideals as shown in Table 9. The next stage involves assigning a value to each alternative according to its preference. A preference value refers to a value that describes the closeness of the alternative to its ideal solution. Alternatives (Ai) with higher preference values are more desirable. Data related to the preference values of each alternative can be seen in Table 10.

After obtaining the supplier evaluation decision matrix, the next step is to calculate the normalization matrix. Normalizing the matrix involves converting the matrix with alternative decisions m and n criteria into a dimension-ed matrix. Below are the results of the normalized supplier evaluation decision matrix.

Furthermore, to determine the Positive Ideal Solution and Negative Ideal Solution matrices, the minimum and maximum values for each sub-criterion need to be identified based on the nature of its attribute, whether it is a benefit or a cost. The minimum and maximum values are derived from the weighted normalized decision matrix. If the attribute is a cost, the Positive Ideal Solution is to minimize the cost, and the Negative Ideal Solution is to maximize the cost. Conversely, if the attribute is a benefit, the Positive Ideal Solution is to maximize the benefit, and the Negative Ideal Solution is to minimize the benefit.

Table 8 Matrix of positive ideal solution (A+) and negative ideal solution (A-)

Criteria	Positive Ideal Solution	Negative Ideal Solution
K1	0.2819	0.2563
K2	0.1948	0.1694
H1	0.3838	0.4203
H2	0.0512	0.0723
P1	0.1070	0.1178
P2	0.3505	0.3824
C1	0.3623	0.3308
C2	0.1273	0.1107
G1	0.1409	0.1164
G2	0.3638	0.3032

Determining the distance between each alternative is done by assessing their relative proximity to the Positive Ideal Solution (A+) and Negative Ideal Solution (A-). The results are as follows as in Table 9.

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Table 9 Distance value from each alternative

Coffee Bean Supplier	D+	D-
S1	0.049268	0.078770
S2	0.046023	0.059339
S3	0.063930	0.067263
S4	0.044167	0.082376
S5	0.082501	0.035778

The calculation of preference values is used to obtain the decision results based on the closeness distance values of each alternative to the ideal solution with the largest value. A higher preference value indicates that the alternative (Ai) has been chosen. The preference values for each Supplier present in Table 10.

Table 10 Preference values

Coffee Bean Supplier	Preference Values	Ranking
S1	0.6152	2
S2	0.5632	3
S3	0.5127	4
S4	0.6510	1
S5	0.3025	5

Based on Table 10, it can be observed that Supplier 1 has a preference value of 0.6152, Supplier 2 has a preference value of 0.5632, Supplier 3 has a preference value of 0.5127, Supplier 4 has a preference value of 0.6510, and Supplier 5 has a preference value of 0.5641. With the highest preference value belonging to Supplier 4, it is concluded that the preferred coffee bean supplier for the company is Supplier 4. Supplier 4 has the highest preference value compared to other suppliers. The weighting results for criteria and sub-criteria in Table 4 indicate that quality is the most important factor in the selection criteria. The weighting result for quality is 0.5761, with the weighting result for sub-criteria Q1 being 0.60 and the weighting result for sub-criteria Q2 being 0.40. The results of this research support previous studies by (Lukmandono et al., 2019; Putri & Pulansari, 2022; Sutoyo & Nusraningrum, 2020; Hasibuan & Jaqin, 2023) which conclude that price is not one of the most influential criteria in supplier selection

To provide accurate weights for each criterion and sub-criterion in supplier evaluation, this study employs AHP, which benefits from pairwise comparison matrices and consistency analysis. Meanwhile, the TOPSIS method is chosen to analyze data and determine supplier priorities (Hasibuan & Jaqin, 2023).

In the data processing results, it's evident that supplier rankings when using AHP resolve issues through pairwise comparisons of criteria and sub-criteria in the ranking process. However, in calculations using the TOPSIS method, different final results are obtained because TOPSIS fundamentally employs calculations of positive and negative ideal solutions. The positive ideal solution is defined as the sum of all best scores achievable for each attribute, while the negative ideal solution consists of all worst scores achieved for each attribute. TOPSIS considers both the distance to the ideal positive solution and the distance to the ideal negative solution by taking relative closeness to the ideal positive solution

This research combines both approaches to identify and select the most advantageous coffee bean suppliers for the company's future needs through careful consideration of relevant factors. In Table 10, it can be observed that the supplier with the highest preference, which can be recommended as the primary supplier for providing coffee bean raw materials, is Supplier 4. This conclusion is based on the data processing conducted using the integration of both approaches.

Based on management policy, both suppliers with the lowest scores can be replaced by other suppliers or will be re-evaluated. To enhance decision-making effectiveness among managers and to support, rather than replace, managers' assessments, this research can be used in the future by businesses as a tool for making scientific and objective decisions, which can assist staff in assessing and solving semi-structured problems.

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4. Conclusion

After processing the data using the AHP & TOPSIS methods, it is concluded that S4 ranks first with a preference value of 0.6510, while the second and third ranks are occupied by S1 and S3, respectively. To establish good cooperation with suppliers, the supplier in the first rank (S4) must also consider the predefined criteria, namely quality, price, delivery, capacity, and warranty & service. After weighting the criteria, it is revealed that the quality criterion takes the first position with an importance level value of 57.6%. Other criteria following in order are capacity, price, warranty & service, and delivery.

Further research is needed to address the limitations in this study. In future research, it is hoped that researchers can explore new methods for supplier selection. This study demonstrates that the integration of AHP-TOPSIS can be employed by companies before choosing a suitable coffee bean supplier. In the future, the company can consider the findings of this research for the sustainability of supplier selection.

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