Medium-sized Garment Company Suppliers Performance Evaluation using Analytical Network Process (ANP) and Technique for Order by Similarity to Ideal Solution (TOPSIS)

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Abstract. KK Convection is a company that produces various types of clothing, including daily work attire, uniforms, shirts, sweaters, and more. The highest demand among its products is for uniforms, and the primary raw material used is cotton tetron fabric (TC). The company relies on five suppliers for tetron fabric. The company has prioritized suppliers offering lower fabric prices to fulfill its material requirements. However, opting for suppliers solely based on low prices may lead to delays in fulfilling fabric orders. This, in turn, affects the overall production timeline. This research aims to assess and evaluate supplier performance through a comprehensive analysis of five key criteria: price, quality, service, delivery, and attitude. Each criterion will be further dissected into several sub-criteria. The assessment of suppliers will involve assigning importance weights to both criteria and sub-criteria using the Analytic Network Process (ANP) method. The resultant weights will serve as crucial inputs for the TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) calculation process, aiding in the identification of the best-performing supplier. The data analysis indicates that the fifth supplier is the optimal choice to ensure efficient and timely fulfillment of fabric orders, thereby enhancing the overall production process.

Keywords: Garment Industry, Supplier Evaluation, TOPSIS, ANP.

1 Introduction

Supply chain management entails the control, planning, and coordination of various aspects within a company, spanning from the procurement of raw materials by suppliers to managing product returns. It encompasses activities from raw material suppliers to product distribution to consumers. The critical element of supplier selection significantly affects the continuous availability of essential raw materials. The assessment and decision-making process regarding the right supplier directly influence product sales prices, quality, and the level of service provided by the supplier (1). KK Convection operates in fashion industry specializing in the production of diverse clothing items, including daily work clothes, uniforms, shirts, sweaters, and more. Uniforms, being in

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high demand, are the most frequently manufactured items, with the primary raw material being cotton fabric. The business owners prioritize top-notch raw materials, swift delivery, and reasonable prices to ensure consumer satisfaction.

However, current evaluation process for KK Convection 's suppliers shows that production volumes often neglect considerations for factors such as performance consistency, price stability, delivery suitability, and reliability. This gap directly affects KK Convection, resulting in elevated product prices, discontent among consumers, and order cancellations. KK Convection currently evaluates suppliers based solely on price, quality, and delivery criteria, emphasizing the necessity for a more comprehensive assessment of supplier performance. The chosen criteria, specifically for fabric raw materials, do not sufficiently encompass all the capabilities and performance aspects crucial for achieving the desired output. Late deliveries of raw materials are a common issue, impacting the evaluation of suppliers.

An analysis of KK Convection 's supplier assessment data reveals disparities in delays and late deliveries among the five suppliers. For instance, Sam Textile in Bandung offers prices ranging from IDR 615,000 to IDR 620,000, with a 10-day delay resulting in significant losses in order completion. This research aims to evaluate the performance of Karina Convection & Garment suppliers based on specific criteria to establish supplier priorities. The research utilizes the Analytical Network Process (ANP) method for weighting supplier criteria and sub-criteria, and the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method to determine alternative priorities based on the distance from the ideal positive and negative solutions. The hope is that the research on KK Convection will yield supplier assessments aligned with the current criteria essential for the company's needs. In light of the background results, the research problem is formulated as follows: What criteria are employed in selecting suppliers and how can supplier criteria be identified to determine the best supplier at KK Convection.

2 Research Methods

This study is designed to assess the performance of suppliers providing fabric raw materials, with the ultimate goal of identifying the most suitable supplier. The research unfolds in three distinct stages: include (1) determining the criteria and sub criteria for evaluating supplier performance, (2) weighting criteria and sub criteria, (3) supplier performance evaluation. By systematically navigating through these stages, this research aims to provide a robust and objective evaluation of fabric raw material suppliers, facilitating informed decision-making in selecting the optimal supplier for KK Convection.

2.1 Criteria and Sub Criteria for Supplier Performance Evaluation

Dickson Framework research has significantly influenced the field of Identification of criteria and sub-criteria for supplier performance assessment, with more than 90% of previous studies (2) referencing his work to establish criteria for forming a hierarchical structure in their respective research problems. Dickson pioneered research aimed at determining, understanding, and analyzing the criteria employed by companies in supplier selection (3). In his study, Dickson distributed questionnaires to 273 staff and purchasing managers across America. Out of the 170 respondents, 23 main criteria were identified and utilized by purchasing managers in supplier selection (3).

Building on this foundation and incorporating insights from expert interviews, our study has distilled the supplier performance assessment criteria to five key factors: quality, price, delivery, service, and attitude. Each criterion and their corresponding sub-criteria are outlined in the following Table 1.

Table 1. Criteria and sub criteria for supplier performance evaluation

No	Criteria	Sub Criteria
1	Price (C1)	Raw material price (C11)
		Payment term (C12)
		Discount (C13)
		Price increase rate (C14)
2	Quality (C2)	Quality assurance (C21)
		Price to quality compatibility (C22)
		Packaging precision (C23)
		Two-way communication (C24)
3	Service (C3)	After service purchase (C31)
		Complaints procedure (C32)
		Response to circumstances (C33)
4	Delivery (C4)	Transportation type (C41)
		Speed of delivery (C42)
		Delivery quantity accuracy (C43)
		Delivery flexibility (C44)
5	Attitudes (C5)	Responsiveness to demand (C51)
		Polite to customers (C52)
		Customers friendly (C53)

2.2 Weighting of criteria and sub-criteria for Evaluating Supplier Performance

The fabric raw material suppliers' performance evaluation using criteria and sub-criteria weighting is conducted using the Analytic Network Process (ANP) method. According to (4), the Analytic Network Process (ANP) is a methodology that assesses the significance of suppliers, considering the relationships between criteria and sub-criteria. The ANP method is an advancement of the Analytical Hierarchy Process (AHP), which can be utilized but exhibits a weakness in this model. The ANP model addresses the limitations of the AHP model, particularly in its ability to establish connections between criteria held by suppliers. The ANP method incorporates two types of linkages: inner independent (within one element) and outer independent (between different elements). Hence, the ANP method is the preferred choice and is also more intricate than the AHP method.

The relationship between criteria and sub-criteria serves as the basis for weighting with the ANP method, illustrating the connections between criteria. The data processing stemming from the weighting results is elucidated as follows.

Table 2. Intensity of importance weighting

Intensity of Interest	Definition
1	Both elements hold equal significance
3	One element carries a slightly higher importance compared to the others
5	One element holds greater importance than the others
7	One element is evidently more crucial than the others
9	One element is unquestionably more significant than the other elements
2,4,6,8	The numerical difference between the two nearest consideration values

The ANP method is implemented through an assessment using a questionnaire and subsequent calculations using Super Decision software. The relationship between criteria and sub-criteria forms the foundation for the ANP Super Decision software model. The design of the questionnaire is intended to capture the relationships between criteria and sub-criteria, serving as a valuable reference in constructing the ANP model (5).

Determination of weights using the ANP method, namely:

1. Calculate the geometric mean value to get the cumulative value of respondents' questionnaire answers so that a decision can be made or get an answer.
2. Super Decision Software used to calculate the geometric mean that has been obtained.
3. Paired questionnaires that have been tested for consistency by looking at a CR smaller than 0.1. The comparison matrix produces a consistency value equal to 0.1, which can be said to be consistent.
4. Normalization of the values for each element is used to determine the importance weight of the sub criteria.

2.3 Supplier Performance Evaluation

Performance evaluation of raw material suppliers is conducted using the TOPSIS method. According to (6), the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method, initially introduced by Yoon and Hwang (7), is employed for solving multi-criteria problems. TOPSIS not only provides a solution for identifying the best and worst alternatives among all available options but also utilizes distance metrics for these comparisons.

The development of TOPSIS in those studies were rooted in the intuition that the alternative with the smallest distance from the positive ideal solution and the largest distance from the negative ideal solution could be determined using Euclidean distance. It is noteworthy that an alternative with the smallest distance from the positive ideal solution may not necessarily have the largest distance from the negative ideal solution. In essence, TOPSIS is a method that simultaneously considers distances to both positive and negative ideal solutions in decision-making.

The decision-making process in TOPSIS involves determining the relative closeness of an alternative to the positive ideal solution. The results of TOPSIS yield a ranking of alternatives based on the value of their relative closeness to the positive ideal solution. This ranked information can then be utilized in decision-making processes. The advantages of the TOPSIS method lie in its practical application for decision-making, its simple and understandable concept, and its ability to measure the relative performance of all decision alternatives.

According to (6), the stages in the TOPSIS method are interconnected to yield the final reference value. The stages for determining decision alternatives using the TOPSIS method are outlined as follows.

1. Prepare a decision matrix
   The beginning of this method is that each solution in decision making to determine alternative i is used as the final decision chosen from other decisions. When the decision matrix is determined, criteria (j) are used as the basis for decision making. Alternative and also the criteria are collected to form a match which is called the decision matrix (X_{ij}).

$$X_{ij} = \begin{pmatrix} x_{11} & x_{12} & - & x_{1n} \\ x_{21} & x_{22} & = & x_{2n} \\ x_{m1} & x_{m2} & - & x_{mn} \end{pmatrix}; i = 1,2, \dots, m \ ; \ j = 1,2, \dots, n \qquad (1)$$

2. Decision Matrix Normalization (r_{ij})
   To produce comparable values, the decision matrix (X_{ij}) normalization matrix (r_{ij}) is carried out using the following formula.

$$rij = \frac{xij}{\sqrt{\sum_{i=1}^{m} xij^2}} \quad i = 1,2, \dots, m \ ; \ j = 1,2, \dots, n \qquad (2)$$

3. Calculation of weighted normalized matrix (v_{ij})
   The decision-making method has a weakness, namely that the determined input is objective when the weight is determined directly by the decision maker. Weighted normalized matrix decision making can be produced by multiplying the attributes contained in the alternatives with previously determined weight values. Network analytical process as a weighting method is used to avoid the weaknesses of the weighting matrix method.

$$wj = rij.vij \qquad (3)$$

4. Calculating the positive ideal solution (A+) and also the negative ideal solution (A)

- Calculating the positive ideal solution (A+)
  Calculation of positive ideal solutions can be obtained from adding up the best values for each attribute. If an attribute is said to be the best, it can be said to be the highest

value. If a cost attribute has the lowest value. The formula for the positive ideal solution (A+) is explained as follows.

$$A^{*} = \left\{\left(\max_{i} vij| \quad j \in J'\right).\left(\min_{i} vij| \quad j \in J'\right)\right\} \tag{4}$$

$$A^{*} = \left\{v_1^{*}, v_2^{*}, \ldots, v_j^{*}, \ldots, v_n^{*}\right\}$$

- Calculating the negative ideal solution (A-)
  The negative ideal solution is the lowest value of each attribute. For example, the crazy profit attribute can then be taken the lowest. If the cost attribute can be taken the highest value. The formula for a negative ideal solution can be explained as follows.

$$A^{*} = \left\{\left(\min_{i} vij| \quad j \in J'\right).\left(\max_{i} vij| \quad j \in J'\right)\right\} \tag{5}$$

$A^{-} = \left\{v_1^{-}, v_2^{-}, \ldots, v_j^{-}, \ldots, v_n^{-}\right\}$; where: j: Profit attribute and j': Cost attribute

5. Calculation of distances to positive ideal solutions and negative ideal solution
   Calculating the distance to positive and negative ideal solutions is a different decision-making stage in the TOPSIS method. Deni's decision method explains finding the best solution by comparing it with the furthest or best solution and can also compare the best or closest solution. Calculate the distance between alternative to i use the positive and negative ideal solutions described as follows.

- Distance calculation with positive ideal solution (S_I^{*})
  Distance calculation with solution positive ideal using the formula as following.

$$S_I^{*} = \sqrt{\sum_{j=1}^{n}\left(vij - v_j^{*}\right)^2} \ ; \ i = 1,2,\ldots,m; \quad v_j^{*} = \text{positive ideal solution to j} \tag{6}$$

- Calculation distance with negative ideal solution (S_I^{-})
  Calculation of distance to a negative ideal solution using the formula as following.

$$S_I^{-} = \sqrt{\sum_{j=1}^{n}\left(vij - v_j^{-}\right)^2} \ ; j = 1,2,\ldots,n; \quad v_j^{-} = \text{negative ideal solution to j} \tag{7}$$

6. Calculation of relative proximity (C_I^{*})
   Relative closeness calculation is the final stage used to find the relative closeness value of each alternative to the ideal solution. The following is the formula used to find the relative closeness value where S_i^{*} is distance of the *i*-th positive ideal solution and S_i^{-} is distance of the *i*-th negative ideal solution.

$$C_I^{*} = \frac{S_i^{-}}{S_i^{*} + S_i^{-}} \tag{8}$$

7. Sort preferences

After calculating the relative closeness, the relative closeness values can be sorted from the largest value to the lowest. The value of the best decision alternative is indicated by the highest value of relative closeness.

3 Result and Discussion

3.1 The Hierarchical Structure of Analytical Network Process (ANP)

The hierarchical structure in the ANP method is utilized for preparation, serving as a basis for supplier assessment and as a reference for determining the criteria and sub-criteria weights. The hierarchical structure in supplier evaluation consists of three levels: goals or objectives, criteria, sub-criteria, and alternatives. The objective of this hierarchical structure is supplier assessment, with criteria encompassing quality, delivery, service, price, and attitude. The hierarchical structure of ANP is depicted in Figure 1.

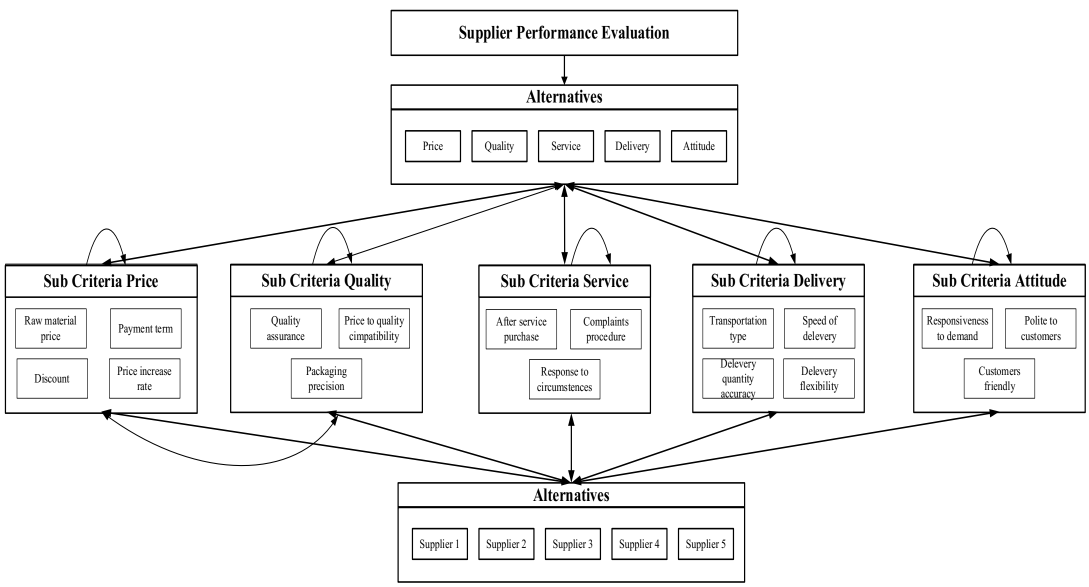

Fig. 1. The hierarchical structure of ANP.

3.2 Priority criteria and sub criteria

Weighting of criteria and sub-criteria to assess supplier performance involves pairwise comparisons conducted by competent experts. The values from these pairwise comparisons are then processed using the Super Decision software. The software produces the weighting results of each criterion and sub-criteria as summarized in Table 3 below. According to the table, the delivery criteria have the highest weight of 0.2308, followed by the quality criteria with a weight of 0.22512.

No	Criteria	Priority of ANP criteria	Sub Criteria	Normalized By All Elements
1	PRICE	0.18338	raw material price	0.18338

			term of payment	0.22512
			discounts	0.20404
			price increase rate	0.2308
			quality assurance	0.15665
			price to quality compatibility	0.35932
2	QUALITY	0.22512		
			packaging precision	0.22143
			two-way communication	0.21548
			service after purchase	0.20377
3	SERVICE	0.20404	compline procedure	0.38449
			response to circumstances	0.28185
			type of transportation	0.33366
			delivery speed	0.35938
4	DELIVERY	0.2308		
			accuracy of delivery quantity	0.20177
			Delivery flexibility	0.18644
			responsiveness to demand	0.25241
5	ATTITUDE	0.15665	polite to customers	0.1312
			customers friendly	0.35784

3.3 Distance Between Alternative Values and Positive and Negative Ideal Solution Matrices

The determination of the distance between the alternative values and the positive and negative ideal solution matrices is derived from the ideal solution data. The results of calculating positive and negative ideal distances can then be explained as follows.

No	Sub Criteria	Suppliers				
		1	2	3	4	5
1	raw material price	0.00198	0.00000	0.00000	0.00049	0.00000
2	term of payment	0.00000	0.00263	0.00000	0.00000	0.00263
3	discounts	0.00000	0.00000	0.00080	0.00000	0.00000
4	rate of price increase	0.00081	0.00000	0.00081	0.00081	0.00000
5	price increase rate	0.00127	0.00127	0.00000	0.00127	0.00000
6	quality assurance	0.00759	0.00000	0.00759	0.00759	0.00190
7	price to quality compatibility	0.00000	0.00211	0.00211	0.00000	0.00000
8	packaging precision	0.00000	0.00000	0.00000	0.00000	0.00000
9	service after purchase	0.00000	0.00000	0.00000	0.00000	0.00036
10	two-way communication	0.00704	0.00176	0.00000	0.00704	0.00000

11	service after purchase	0.00153	0.00153	0.00153	0.00153	0.00000
12	compline procedure	0.00000	0.00655	0.00655	0.00164	0.00655
13	response to circumstances	0.00671	0.00000	0.00671	0.00671	0.00000
14	type of transportation	0.00078	0.00078	0.00000	0.00078	0.00078
15	delivery speed	0.00042	0.00170	0.00042	0.00042	0.00000
16	accuracy of delivery quantity	0.00000	0.00000	0.00000	0.00000	0.00000
17	Polite towards buyers	0.00033	0.00033	0.00033	0.00000	0.00033
18	Delivery flexibility	0.00246	0.00246	0.00246	0.00000	0.00246
	On+	0.17587	0.14534	0.17121	0.16820	0.12253

Based on Table 4, to determine the positive ideal solution value, identify the largest value among all suppliers. This represents a summary of the positive ideal distance calculations, derived by multiplying the positive ideal solution with the weighted normalization matrix value. The supplier with the highest positive ideal distance value is identified as supplier 0, while the supplier with the lowest positive ideal distance is supplier 3 with a value of 0.

No	Sub Criteria	Suppliers				
		1	2	3	4	5
1	raw material price	0.00198	0.00000	0.00000	0.00049	0.00000
2	term of payment	0.00000	0.00263	0.00000	0.00000	0.00263
3	discounts	0.00000	0.00000	0.00080	0.00000	0.00000
4	rate of price increase	0.00081	0.00000	0.00081	0.00081	0.00000
5	price increase rate	0.00127	0.00127	0.00000	0.00127	0.00000
6	quality assurance	0.00759	0.00000	0.00759	0.00759	0.00190
7	price to quality compatibility	0.00000	0.00211	0.00211	0.00000	0.00000
8	packaging precision	0.00000	0.00000	0.00000	0.00000	0.00000
9	service after purchase	0.00000	0.00000	0.00000	0.00000	0.00036
10	two-way communication	0.00704	0.00176	0.00000	0.00704	0.00000
11	service after purchase	0.00153	0.00153	0.00153	0.00153	0.00000
12	compline procedure	0.00000	0.00655	0.00655	0.00164	0.00655
13	response to circumstances	0.00671	0.00000	0.00671	0.00671	0.00000
14	type of transportation	0.00078	0.00078	0.00000	0.00078	0.00078
15	delivery speed	0.00042	0.00170	0.00042	0.00042	0.00000
16	accuracy of delivery quantity	0.00000	0.00000	0.00000	0.00000	0.00000
17	Polite towards buyers	0.00033	0.00033	0.00033	0.00000	0.00033
18	Delivery flexibility	0.00246	0.00246	0.00246	0.00000	0.00246
	On+	0.17587	0.14534	0.17121	0.16820	0.12253

Based on Table 5, in order to determine the negative ideal solution value, identify the lowest value among all suppliers. This represents a summary of the negative ideal distance calculations, obtained by multiplying the negative ideal solution with the weighted normalization matrix value. The supplier with the lowest negative ideal distance value is supplier 0, while the supplier with the largest negative ideal distance is supplier 3 with a value of 0.

Table 3. Alternative ranking

Supplier Name	VI	Percentage	Rank
Supplier 1	0.7586	15%	4
Supplier 2	1.1147	23%	2
Supplier 3	0.8234	17%	3
Supplier 4	0.7366	15%	5
Supplier 5	1.4726	30%	1
Total	4.9059	100%	

Based on Table 6, the preference value for supplier ranking is derived by calculating the Vi value, obtained by dividing the positive ideal distance and negative ideal distance for each supplier. The calculations yield the highest percentage value for supplier 5, reaching a preference value of 1.4726, corresponding to 30%. This indicates that supplier 5 is the most favorable alternative and can be considered as a suitable fabric supplier for KK Convection. The second-ranked supplier is supplier 2, with a preference value of 1.1147, representing 23%. The preference value serves as a guide in determining the best supplier, with the understanding that a higher preference value signifies a more favorable choice among alternative suppliers.

4 Conclusion

This study seeks to assess supplier performance by examining five evaluation criteria: price, quality, service, delivery, and attitude, each comprising various sub-criteria. The criteria and sub-criteria for supplier evaluation will be assigned importance weights through the Analytic Network Process (ANP) method. The weighting results will be utilized in the TOPSIS calculation process to determine the most suitable supplier. According to the TOPSIS calculations, it is evident that supplier 5 demonstrates the best performance, having the highest preference value of 1.4726, representing 30%. The second-ranked supplier is supplier 2, with a preference value of 1.1147, corresponding to 23%. The preference value serves as a benchmark for determining the best supplier, where a higher preference value indicates a more favorable selection among alternative suppliers. In conclusion, the study suggests that a greater preference value contributes to an improved selection of alternative suppliers.

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