

Integrated ANP and TOPSIS Method for Supplier Performance Assessment

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ABSTRACT

A supplier has become one of the main factors that influence a company's supply chain activities. Supplier assessment is vital as suppliers have different performance. This study aims at assessing supplier performance using the integration of ANP and TOPSIS methods. Supplier performance assessment was based on supplier criteria indicators. The weighting criteria used ANP was used to determine the most significant influence criteria of supplier performance. Furthermore, TOPSIS was also employed to obtain supplier preference. Eight criteria and twenty-five sub-criteria were used for the supplier performance assessment. The three highest sub-criteria were specification of quality, the flexibility of order changes, and production capacity. The priority results for suppliers were sorted from the highest to lowest ratio values.



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1. Introduction

A supplier is one of the factors that influence the increase in supply chain activities in manufacturing companies. In product development and new product design, supplier involvement significantly assists the entire supply chain [1]. The supplier is an organization that provides resources needed by customers, such as raw materials and services [2]. Manufacturing companies need suppliers to provide materials in their production process. The cost of purchasing raw materials is considerably high as 50% - 70% of the production costs are used in purchasing raw materials [3]. Supplier performance affects the company. A supplier's price may change the company's profit as it can increase by more than 60% of operational costs [4].

Criteria in supplier performance assessment have become essential aspects of assessing suppliers. Supplier selection is a process including identification, evaluation, and contract with the suppliers [5]. Supplier selection is one of the most crucial components in supply chain management [6]. Hence, supplier selection has been a popular topic in the manufacturing industry. Since purchasing raw material purchase may



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consume 40 to 80 percent of the total production costs, it affects company performance [7]. Choosing the right supplier can reduce purchasing costs, increase profit, reduce lead time, upgrade consumer satisfaction, and intensify company performance [8]. It also can improve company performance [3]. Supplier evaluation and selection is a complicated activity as it involves many criteria [9] [10] [11]. Various criteria must be considered in the process of decision-making [12].

Several studies have been carried out in supplier selection/evaluation. Generally, evaluation and supplier selection use qualitative and quantitative approaches [13]. Simić, et al. [12] reviewed the fuzzy set theory and models for supplier performance. Yusuf et al. [14] proposed integrating the Analytical Hierarchy Process (AHP) and TOPSIS. They offered six criteria and fourteen sub-criteria. Sarkar and Mohapatra [15] used a fuzzy set approach. Twenty-three criteria were proposed for supplier selection, such as price, capability, and quality. Pangestu [16] offered the Fuzzy Analytical Hierarchy Process. He employed some criteria such as rejection rate, payment level, delivery, and price. Azwir and Pasaribu [17] used the ANP method with four criteria: rejected rate, payment transaction, delivery, and price. Khoiro [18] proposed AHP and Taguchi Loss function. This study used the criteria, including price, quality, delivery, underweight, availability, payment system, guarantee policy, and repair service. Lin, et al. [19] developed methods of Analytic Network Process (ANP), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), and Linear Programming (LP). Twenty-one criteria were used as the basis for supplier assessment [19].

Based on previous studies, several studies have systematically investigated supplier selection/evaluation. One famous study was conducted by Yuliandono et al. [20]. They considered fourteen criteria for supplier selection. FAHP and TOPSIS were proposed to the evaluation/selection suppliers. However, this research has not considered relationships between the criteria. Very little research has addressed the selection of suppliers to examine the network model between the criteria and sub-criteria. It is deemed essential to find out the relationships between criteria and sub-criteria. Criteria and sub-criteria are categorized as influential and influenced, respectively. This study aims to integrate the ANP and TOPSIS methods into supplier performance assessment. Several methods can be combined with the quality of decision-making [15]. Hence, the integration between ANP and TOPSIS is proposed to evaluate supplier performance to improve decision-making quality. Supplier selection and assessment may use several factors [21]. ANP is applied to criteria weighting due to its superiority in obtaining dependency and interdependence interactions between criteria and sub-criteria [22]. Weights of criteria and sub-criteria in ANP are obtained through TOPSIS in evaluating supplier performance. TOPSIS is an effective method to find the most efficient alternative [23]. Hence, It is expected that this research will contribute to a deeper understanding of supplier performance assessment, specifically on the ANP and TOPSIS methods.

2. Methods

In this section, we proposed a framework for supplier performance assessment. It can be seen in Fig. 1. This study suggested the integration of ANP and TOPSIS to evaluate supplier performance. The ANP was used to weight the criteria and sub-criteria. The weights of criteria and sub-criteria in ANP were then used in TOPSIS to assess supplier performance. The steps of ANP and TOPSIS are explained below.



2.1 Identification of criteria and sub-criteria

The first step was identifying the criteria and sub-criteria used in selecting suppliers. The criteria for supplier assessment depend on the company's supply chain strategy [24]. The criteria were determined from the literature review and discussion with experts [13]. In this study, ten criteria and twenty-nine sub-criteria from the literature review are shown in Table 1.

Table 1. Criteria and sub-criteria

Criteria	Sub-criteria	References
Quality	Quality specification	[22], [12], [5], [25], [26], [6]
	Rejection percentage	[22], [5]
	Quality consistency	[22], [12], [6]
Delivery	Packaging ability	[22], [12], [6]
	On-time delivery	[22], [12], [5], [6]
	On-time delivery quantity	[22], [12]
	Type & condition accuracy of raw materials	[22], [5]
Price	Product price negotiation	[22], [12]
	Price consistency	[22], [12], [5], [6]
	Low price	Proposed
Geographical Location	Factory / Shipper location	[22], [12], [5], [6]
Reputation & Performance	Good performance history	[22], [12], [5], [6]
	Long term cooperation	[22], [12]
	Completeness of document requirement	[22], [12], [5], [6]
Responsiveness	Related to product information	[26], [5]
	Claim policies	[22], [6]
	Related to improvements	[22], [6]
Flexibility	Payment flexibility	[22], [5]
	Order change flexibility	[22], [5]
	Delivery flexibility	[22], [5]
Product Design & Development	Ability to conduct the product R&D	[22]
	Design development	[22]
Management & Organization	Organizational culture suitability	[22]
	Labor relations record	[22], [12]
	Training	[22], [12]
Production Facility & Capacity	Production capacity	[22]
	Minimum orders	[22]
	Lead time	[22]
	Sophisticated Production Equipment	Proposed

2.2 Assessment of criteria and sub-criteria

All criteria and sub-criteria were assessed according to [Table 1](#). The assessment was to select critical criteria and sub-criteria on the supplier performance assessment. The results of the assessment of criteria and sub-criteria were weighted based on the ANP procedures. We proposed assessing criteria and sub-criteria using five levels of importance scale, ranging from 1 (not important) to 5 (very important). The sub-criteria with an average value below 3 indicated it was not important.

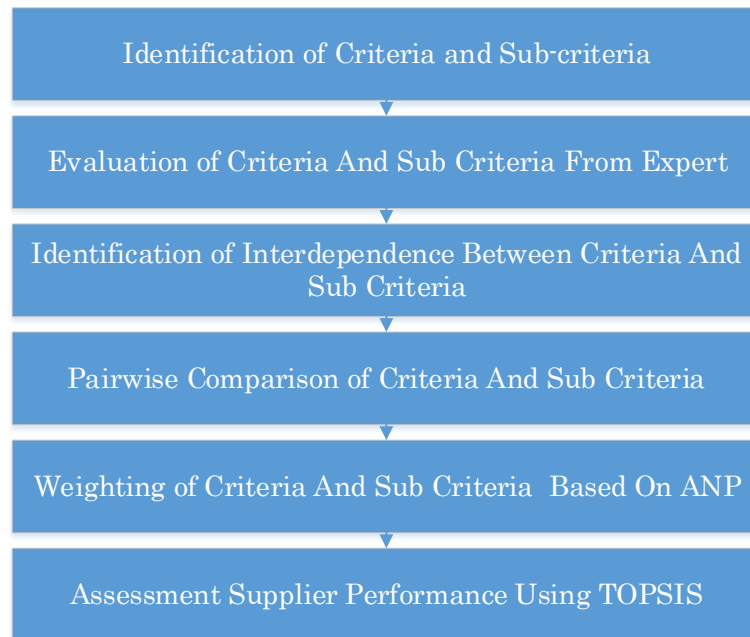


Fig. 1. Proposed Framework for supplier performance assessment

2.3 Analytical Network Process (ANP)

As stated earlier, ANP was used to assess the weights of criteria and sub-criteria. This study employed ANP modified from [Saaty and Vargas \[27\]](#). The steps of ANP are as follows:

1. Determining the Network Relationship

Based on the assessed criteria and sub-criteria, this study developed interdependencies between the criteria. At this stage, questionnaires were used to determine the relationship between the criteria. Experts filled out the questionnaires. The relationship between the criteria was described by arrows [\[24\]](#). The ANP model was developed by [Saaty \[28\]](#) based on the relation of the interdependencies between the sub-criteria [\[29\]](#). We created a relationship between the criteria, in which the arrow indicated dependency between the networks.

2. Determining the Weights

At the last stage, ANP was employed to determine the criteria and sub-criteria weights. In this stage, a pairwise comparison was used based on the interdependence criteria in the previous step. Super Decision Software [\[25\]](#) was made use to determine the weights of the criteria and sub-criteria. The criteria and sub-criteria weights were utilized to assess supplier performance through the TOPSIS method. The TOPSIS procedure is described in the next section.

2.4 TOPSIS Method

This study employed the TOPSIS method for the supplier performance assessment. The weights of criteria and sub-criteria at the TOPSIS stage were obtained from the ANP method. The principle of the TOPSIS method was chosen based on the distance from the ideal solution. The positive ideal solution is defined as the sum of the best values that can be achieved for each attribute. On the other hand, the negative ideal solution consists of all the lowest values that can be achieved for each quality [22]. The stages of the TOPSIS method in this study were based on [30].

2.5 Data Collection

A case study was conducted in manufacturing companies in the automotive industry. Three experts were involved as respondents in this study. Respondents were chosen based on their responsibilities in the procurement department. The three respondents were the procurement and finance department manager, head of the procurement department, and procurement department staff. The respondents filled out the questionnaires about supplier performance assessment. The supplier performance assessment itself was conducted in five suppliers: Supplier 1, Supplier 2, Supplier 3, Supplier 4, and Supplier 5.

Four questionnaires were used to assess supplier performance. The first questionnaire was to evaluate the criteria and sub-criteria. It used five levels of importance scale, ranging from 1 (not important) to 5 (very important). The second questionnaire was to determine the interdependence (network relations) of the criteria. It used a checklist. The third questionnaire was the pairwise comparison questionnaire (ANP procedure). Three questions in the pairwise comparison questionnaire were the criteria question between the inner cluster sub-criteria questions and the outer cluster sub-criteria question. These questions used nine levels of importance ranging from 1 (equally important) to 9 (very important). The fourth questionnaire was supplier performance assessment using TOPSIS. It used five levels of supplier assessment scale sub-criteria, such as 1 (very poor) to 5 (very high).

3. Results and Discussion

3.1 Results of Evaluation criteria and sub-criteria and interdependence

The average importance level of the criteria and sub-criteria (questionnaire 1) is presented in Table 2. It shows the criteria and sub-criteria with the average values based on the questionnaires filled out by three respondents. This result shows eight criteria and twenty-five sub-criteria as the indicators in the assessment of supplier performance. On the other hand, two criteria and four sub-criteria were not selected as indicators of the assessment.

The relationship between the sub-criteria (the second questionnaire) shows that dependency between the elements occurred. In Table 3, the yellow cell box shows that more than one respondent assessed the influence of one sub-criteria toward another sub-criteria. However, the orange cell box describes that only one respondent evaluated the impact—for example, three respondents assessed the influence of B1 criteria on C2 criteria. Based on Table 3, the quality criterion was a criterion that affected other criteria.

Furthermore, This result also describes interdependence between the criteria. Fig. 2 shows a network relation model between the criteria based on the results of the second questionnaire. The reputation and performance were influenced by the design and

development, quality, price, delivery, responsive, and flexibility clusters. However, reputation and performance influenced the quality and production facility and capacity.

Table 2. Average importance level of criteria and sub-criteria (questionnaire 1)

No	Description	Value	No	Description	Value
A	Quality	5.00	F	Flexibility	4.67
A1	Quality specification	4.67	F1	Payment flexibility	4.33
A2	Rejection percentage	4.33	F2	Order change flexibility	4.33
A3	Quality consistency	4.33	F3	Delivery flexibility	3.33
A4	Packaging ability	4.00	G	Design & Development	4.00
B	Delivery	4.00	G1	Ability to conduct the product R&D	4.00
B1	On-time delivery	4.33	G2	Design development	3.67
B2	On-time delivery quantity	4.00	H	Production Facilities & Capacities	4.33
B3	Types & conditions accuracy	4.33	H1	Production capacity	4.00
C	Price	4.67	H2	Minimum orders	4.67
C1	Product price negotiations	4.67	H3	Lead time	3.67
C2	Price consistency	3.67	H4	Sophisticated production equipment	4.33
C3	Low price	3.33	I	Geographical Location	2.33
D	Reputation & Performance	4.00	I1	Factory / Shipper location	2.33
D1	Good performance history	3.67	J	Management & Organization	2.67
D2	Long term cooperation	3.00	J1	Suitability of organizational culture	2.33
D3	Completeness of document requirements	4.33	J2	Labor relations record	2.33
E	Responsiveness	3.67	J3	Training	2.67
E1	Relate to product information	3.67			
E2	Claim policies	4.33			
E3	Relate to improvements	4.67			

Table 3. Recapitulation of Results by Network Between Sub-Criteria

		Influenced																									
		A	A	A	A	B	B	B	C	C	C	D	D	D	E	E	E	F	F	F	G	G	H	H	H	H	
		1	2	3	4	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	1	2	3	4	
Influences	A1		3	2	3	2	3			3	1	2									2						
	A2	2		2		2	3	2			1											2					
	A3								3	2		3	3	3													
	A4	3	3	3		3	2	2			1	2															
	B1									3		2	3														
	B2					3						2	3														
	B3			2						3																	
	C1	1		1	1							3							3								
	C2	2		1	1							3	2	1					3								
	C3	2								1				1													
	D1												3	3											2		
	D2												2												1		
	D3	2				2							3	3										3			
	E1									1			3					2									
	E2									1			3	2		2		2									
	E3												2	3		2	3										
F1									3			2	2														
F2												2	3		3							2			2		
F3												2															
G1	2					2	2	3			3		3	2		2		3						3			
G2	3									3		3			2		3					2					
H1						2	3						1							3				3	3		
H2													1							3							
H3						3						1							3				2	3			
H4	2								1		1										3		3	1	2		

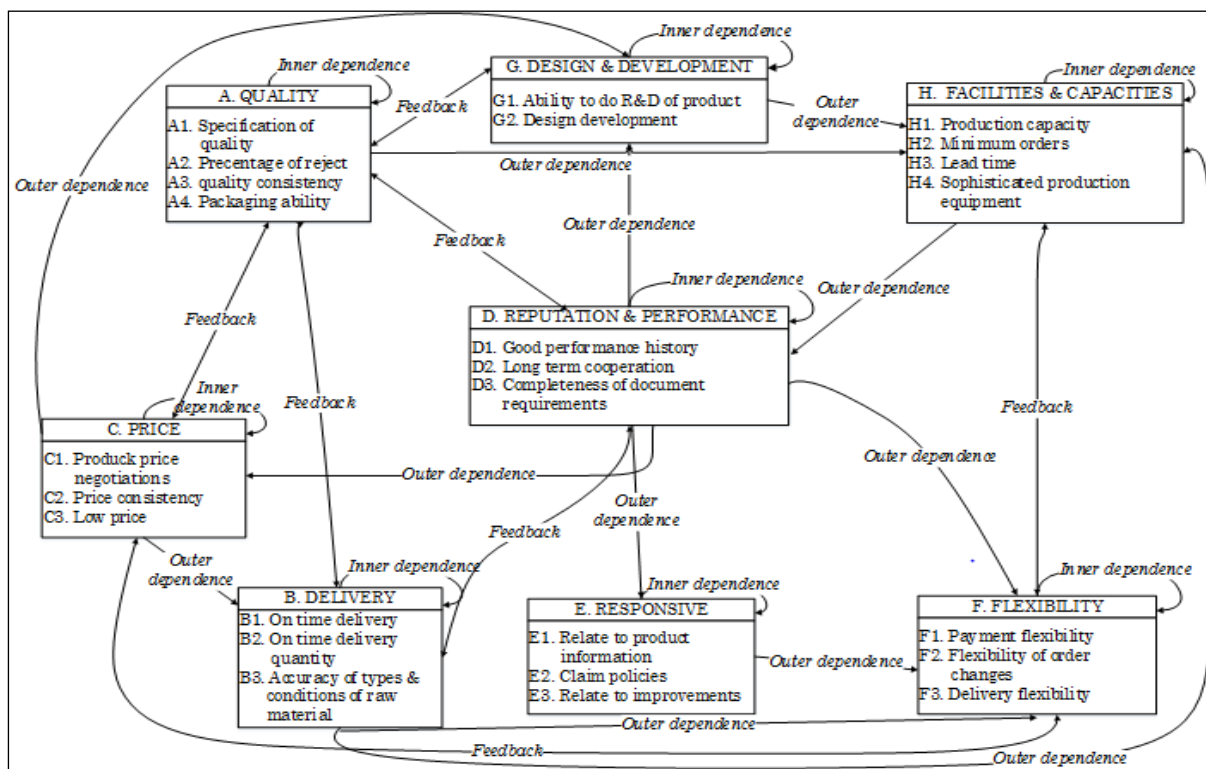


Fig. 2. Model for Determining Criteria that Influences Supplier Performance Assessment Using ANP

3.1 ANP Model Based on Network

Three types of networks in ANP included emotional dependence, external dependence, and feedback (influence between groups). Fig. 2 shows that each cluster had an inner dependency relationship. It occurred when elements in the same cluster had a meaningful relationship. The example of the inner dependency network was quality criteria. Respondents assessed the quality according to the specifications influenced by the percentage of rejected raw materials and packaging accuracy. Meanwhile, when the packaging is not proper, it also affected the quality of the raw materials. It is in line with the statement in the research by Kurniawati et al. [26].

The outer dependence relationship in the quality criteria was also present. The sophistication of the production equipment affected the quality according to the specifications. Besides, the quality criteria, such as the quality according to specifications and quality consistency, influenced price consistency. The findings are consistent with Pujotomo, et al. [22] as they showed the effect of quality consistency toward price consistency.

The feedback network was the cluster element that affected the elements in other clusters and vice versa. Based on the results in Fig. 3, the relationship in the feedbacks between the criteria occurred. The quality criteria had feedback toward delivery. This study confirms the results of the study by Kurniati et al. [26]. They found out the interrelationship between quality criteria and delivery. The results of the study are also in line with Ekawati et al. [31].

		Influenced																								
		A1	A2	A3	A4	B1	B2	B3	C1	C2	C3	D1	D2	D3	E1	E2	E3	F1	F2	F3	G1	G2	H1	H2	H3	H4
influences	A1	Inner Dependence				Feedback			Feedback			Feedback			Feedback											
	A2	Inner Dependence				Feedback			Feedback			Feedback			Feedback											
	A3	Inner Dependence				Feedback			Feedback			Feedback			Feedback											
	A4	Inner Dependence				Feedback			Feedback			Feedback			Feedback											
	B1	Feedback				Inner Dependence			Outer Dependence			Feedback														
	B2	Feedback				Inner Dependence			Outer Dependence			Feedback														
	B3	Feedback				Inner Dependence			Outer Dependence			Feedback														
	C1	Feedback				Inner Dependence			Outer Dependence			Feedback														
	C2	Feedback				Inner Dependence			Outer Dependence			Feedback														
	C3	Feedback				Inner Dependence			Outer Dependence			Feedback														
	D1	Feedback				Feedback			Inner Dependence			Outer Dependence														
	D2	Feedback				Feedback			Inner Dependence			Outer Dependence														
	D3	Feedback				Feedback			Inner Dependence			Outer Dependence														
	E1								Outer Dependence			Inner Dependence														
	E2								Outer Dependence			Inner Dependence														
	E3								Outer Dependence			Inner Dependence														
F1					Outer Cluster			Feedback			Outer Dependence			Outer Dependence			Inner Dependence			Feedback						
F2					Outer Cluster			Feedback			Outer Dependence			Outer Dependence			Inner Dependence			Feedback						
F3					Outer Cluster			Feedback			Outer Dependence			Outer Dependence			Inner Dependence			Feedback						
G1	Feedback				Outer Dependence			Outer Dependence			Outer Dependence			Inner Dependence												
G2	Feedback				Outer Dependence			Outer Dependence			Outer Dependence			Inner Dependence												
H1	Outer Dependence				Outer Cluster			Feedback			Outer Dependence			Inner Dependence												
H2	Outer Dependence				Outer Cluster			Feedback			Outer Dependence			Inner Dependence												
H3	Outer Dependence				Outer Cluster			Feedback			Outer Dependence			Inner Dependence												
H4	Outer Dependence				Outer Cluster			Feedback			Outer Dependence			Inner Dependence												

Fig. 3. Network (interdependence) between elements

Table 4. Results of Weighting Criteria and Sub Criteria using the ANP method

Sub-criteria	Weight of criteria	Weights in Cluster	Weight of Sub-criteria	The Sequence
Ability to do R&D of the product	0.051	0.677	0.034	15
Design development		0.323	0.016	18
Production capacity		0.365	0.095	3
Sophisticated production equipment	0.259	0.218	0.057	6
Lead time		0.244	0.063	5
Minimum orders		0.173	0.045	9
Payment flexibility	0.141	0.025	0.004	22
Delivery flexibility		0.287	0.041	12
Order changes flexibility		0.688	0.097	2
Low price	0.088	0.216	0.019	17
Price consistency		0.437	0.038	13
Product price negotiations		0.347	0.03	16
Packaging ability	0.3	0.145	0.043	12
Quality consistency		0.168	0.05	8
Quality specification		0.399	0.12	1
Rejection percentage	0.068	0.288	0.087	4
Types & conditions		0.796	0.054	7
On-time delivery quantity		0.081	0.005	20
On-time delivery	0.084	0.123	0.008	19
Document requirements		0.525	0.044	10
Long term cooperation		0.034	0.003	23
Good performance history	0.009	0.441	0.037	14
Claim policies		0.294	0.003	24
Related to product information		0.233	0.002	25
Related to improvements		0.473	0.004	21

Table 4 shows the results of the weighting of the criteria and sub-criteria utilizing ANP. It shows the weights of the criteria and sub-criteria of each cluster. The criteria with the highest weights were quality, facility and production capacity, and requirement. Furthermore, the five most essential sub-criteria were quality according to specifications, changes in the number of orders, production capacity, percentage of rejected raw materials, and production lead time. Quality, according to the specifications, was the most crucial sub-criteria in supplier performance assessment. This result is by Pujotomo, et al [22], Taherdoost and Brard [5], Kurniawati, et al. [26], and Rashidi and Cullinane [25].

The weight sub-criteria assessment of supplier performance shows that the company attached great importance to the specifications and four other sub-criteria. Furthermore, the lowest weight is in the responsiveness sub-criteria, both product-related information and claims. In other words, responsiveness was the little significant indicator.

3.2 Priority of Alternative Supplier based on TOPSIS

Fig. 4 describes the percentage of preferences for supplier performance assessment based on TOPSIS. Five suppliers were assessed based on the twenty-five sub-criteria. Based on the assessment, Supplier 1 had a high level of preference. These results indicate the effective integration of ANP and TOPSIS used in supplier performance assessment.

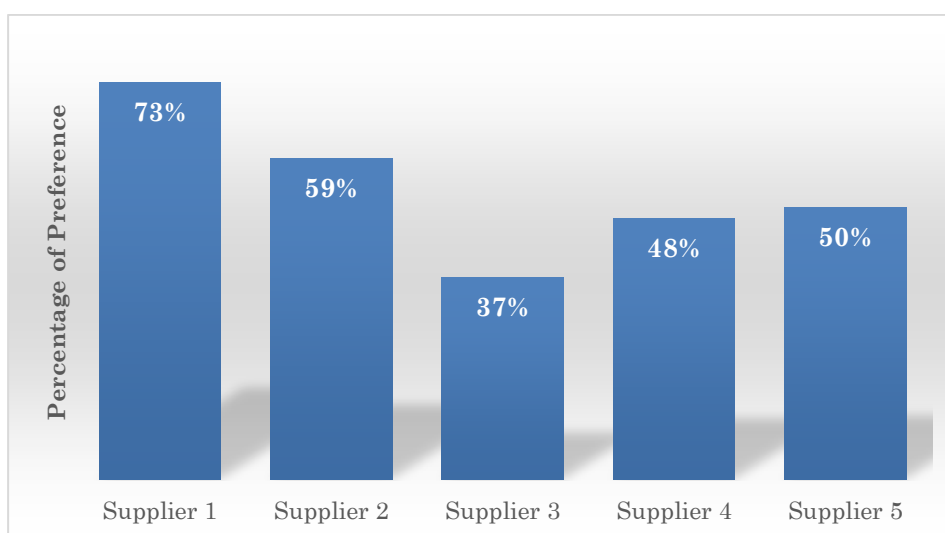


Fig. 4. Preference Percentage of Each Supplier

4. Conclusions

This study aims to integrate the ANP method and the TOPSIS method into supplier performance assessment. The eight criteria used in the assessment consisted of quality criteria, shipping criteria, price criteria, reputation and performance criteria, flexibility criteria, responsive criteria, product development and design criteria, and facility and production capacity criteria. Twenty-five sub-criteria were selected for supplier performance assessment.

The result shows the main criteria in supplier performance assessment were quality criteria, facilities and production capacity criteria, flexibility criteria, price criteria, reputation and performance, delivery, design and development, and responsiveness. The most considerable sub-criteria was quality according to specifications, flexibility in changing the number of orders, production capacity, and percentage of

rejected raw material. These results indicate the effective integration of ANP and TOPSIS used in supplier performance assessment.

This study has limitations in the scope of criteria and sub-criteria chosen by the company. Hence, the Focus Group Discussion (FGD) process may give better results. Besides, integrating the ANP-TOPSIS methods with other procedures can be developed to provide a better solution.

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