Analysis of Performance Evaluation of Packing Box Suppliers Using the Analytical Hierarchy Process (AHP) Method at ABC Company

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Abstract. ABC company is an industrial company manufacturing electrical equipment, most of the products produced by ABC company will generally require the use of packing boxes so that these products can be distributed in good condition. Problems that still often occur with suppliers in meeting the needs of packing boxes are delays in delivery, the presence of defects goods and the occurrence of a mismatch in the number of packing boxes sent by suppliers. This study aims to determine the priority of criteria & sub criteria and analyze the performance of packing box suppliers through the Vendor Performance Indicator (VPI) framework of Quality, Cost, Delivery, Flexibility, and Responsiveness (QCDFR) using the Analytical Hierarchy Process (AHP) method. Based on the results of this study, the top weight value has been obtained, namely the quality criteria (0.50), the lowest weight criteria are the cost criteria (0.04). Through this research also shows that Supplier Z is considered the supplier with the best performance with a weight of (0.582). Then, the second priority supplier is Supplier Y (0.305) and the last priority is Supplier X (0.116).

Keywords: Analytical Hierarchy Process (AHP), Vendor Performance Indicator, Supplier Performance Evaluation.

1 Introduction

The industrial world will always face very fast-paced competitive conditions. This can be noted by the many demands to continue to make improvements in all aspects that must be met in order to continue to compete in the industrial world. Meanwhile, the concept of planning for improvements made to increase the productivity of a company is not only pursued through production activities alone, but it can be pursued through increasing supplier productivity [1]. The evaluation activity of a supplier is an essential aspect in the supply chain, this is because supplier evaluation is one of the company's steps in order to compete with other companies in meeting customer satisfaction and maintaining the company's service level in meeting the needs of customers. [2]

ABC company is a company in the manufacturing industry electrical equipment. Most of the products produced by ABC company will generally require the use of packaging to be distributed to customers, one type of packaging that is often used by ABC company is packing boxes. ABC company has 3 (three) suppliers including supplier X, supplier Y and supplier Z. Problems that often occur in meeting the needs of packing boxes at ABC company are delays in delivery from the agreed schedule, there are defects goods and the occurrence of mismatching packing boxes ordered in the purchase order (PO) sent by the supplier , thus causing a stop line on the production line due to stock out and hampering production activities

in ABC company. Based on information from the Senior Procurement Buyer, it is conveyed that the evaluation system at ABC company itself applies the SAM (Supplier Approval Module) assessment which is only qualified once at the beginning and this is considered ineffective in monitoring the performance of a supplier.

Table 1. Packing box order 2023

PACKING BOX ORDER **JAN - MAY 2023**		
Month	*Order*	*Good Receiving* **(GR)**
Jan	922060 pcs	892205 pcs
Feb	630400 pcs	784348 pcs
Mar	863158 pcs	690163 pcs
Apr	783040 pcs	765876 pcs
May	829724 pcs	816149 pcs

Through **Table 1.** above states that there is a mismatch in the packing box ordered on the purchase order (PO) with the packing box received or Good Receiving (GR) which occurs throughout January to May 2023. This is often caused by the unavailability of inventory stock at the supplier.

In this study, we will evaluate the performance of Packing box suppliers at ABC company by trying to analyze the criteria and sub-criteria that have an influence in the activity of evaluating the performance of packing box suppliers and also to find out which suppliers have the best performance at ABC company by applying the Vendor Performance Indicator (VPI) approach with the Quality, Cost, Delivery, Flexibility, and Responsiveness (QCDFR) framework, with the analysis of the Analytical Hierarchy Process (AHP) method designed by Prof. Thomas L. Saaty in 1970 as decision making.

2 Literature Review

2.1 Supply Chain Management

Definition of Supply Chain Management according to [3] supply chain management is a series of approaches used to effectively integrate suppliers, manufacturers, warehouses and stores so that supplies of goods can be produced and distributed in the right quantity, to the right location, and at the right time so that the cost of the entire system can be minimized while trying to satisfy needs and services. According to [4] supply chain management can be said to be a comprehensive approach in utilizing information technology to coordinate all components of the supply chain, from suppliers to retailers, with the aim of delivering products to end consumers. Meanwhile, the supply chain not only covers producers and suppliers, but also covers transportation, retailer warehouses and customers. The goal of supply chain management is to achieve minimum costs and maximum service levels [5].

2.2 Supplier

Supplier or what can also be said as a supplier, is defined as a group or organization that has the responsibility to meet the needs of a party or other company in the form of goods or services that have been based on previously agreed criteria and specifications. Suppliers are an integral element in Supply Chain Management that cannot be separated and have a significant impact on the operational continuity of the company [6]. For companies, suppliers are the

party that provides or fulfills the first material, which can be (raw materials, raw materials, spare parts and so on). Suppliers are one of the stakeholders, more relevant to the success of manufacturers or producers than other businesses, all companies rely on the level of products and services from other businesses to support the company's ability to serve customers [7]. Suppliers play a crucial role as they ensure a continuous and consistent flow of materials over an extended period. The challenge in supplier selection arises from the company's extensive supplier base, where each supplier comes with its own set of strengths and weaknesses [8].

2.3 Vendor Performance Indicator (VPI)

2.3.1 Definition of Vendor Performance Indicator (VPI)

Vendor Performance Indicator is a management method for measuring supplier performance that is carried out comprehensively and adapts to the needs and requirements of the company [9], this method is also effective in showing the performance of the supplier's performance. To guarantee production continuity in the face of raw material shortages, it is customary to engage multiple suppliers for each product item. Additionally, to secure the consistency of material delivery in alignment with quality benchmarks, regular supplier assessments must be conducted. The selection of suppliers is contingent on their ability to accommodate variations in order specifications, considering not solely the price but also the overall material procurement expenses.

2.3.2 Quality, Cost, Delivery, Flexibility, Responsiveness (QCDFR)

Vendor Performance Indicator (VPI) framework in the form of Quality, Cost, Delivery, Flexibility, Responsiveness (QCDFR) [10] [11] includes: a) Quality: Regarding the supplier's ability to fulfill quality according to predetermined standards. b) Cost: Relates to the price level of raw materials offered by suppliers. c) Delivery: Relates to the ability to fulfill quantity and delivery time. d) Flexibility: Relates to the ability to fulfill demand if there are changes in quantity and delivery time. f) Responsiveness: Relates to the supplier's ability to respond to problems in fulfilling requests and delivery schedules.

2.4 Analytical Hierarchy Process (AHP)

The Analytical Hierarchy Process (AHP) method is a method developed by Prof. Thomas Lorie Saaty from Wharton Business School in 1970 which can be used to solve a complex problem with many aspects or criteria taken [12]. It can be said that the AHP method is a powerful and flexible decision-making tool, the method can support in the process of setting priorities and making decisions in qualitative and quantitative aspects involved and both must be considered [11]. This AHP method not only contributes to the selection of the right decision, but the method can provide clear and precise thinking and reasoning.

The primary instrument of this approach is a functional hierarchy, with human perception serving as the primary input. Through hierarchical structuring, a multifaceted and unorganized issue is dissected into its constituent groups, which are subsequently structured within a hierarchical framework. Employing this hierarchical method, a complicated problem can be deconstructed into its constituent groups, which are then organized hierarchically to enhance the problem's structural clarity and systematic arrangement.

3 Research Methods

In this study, researchers used descriptive research methods with a quantitative approach. A quantitative approach is research that requires the use of many numbers, starting from collecting data, interpreting the data, and presenting the result [13]. In this quantitative descriptive method, it is adjusted to the use of research variables that focus on current problems and phenomena that are currently occurring with the presentation of research results in the form of numbers that have their own explanation [10]. The operational variables for this research are shown in the following table:

Table 2. Operational variables

Variables	Variable Dimensions	Indicator	Scale of Measurement	Source
Packing Box Supplier Performance Evaluation	Quality	Product quality conforms to company standards	Pairwise Comparison Scale	(Pramita & Wirawan, 2019)
		Ability to consistently deliver quality		
	Cost	Price Suitability		
		Convenience and Payment terms		
		Willingness to Negotiate Price		
	Delivery	Conformity of request specifications and the number of packing boxes that will be sent.		
		Speed of delivery time		
	Flexibility	Fulfillment of requests for changes in the number of packing boxes that are ordered		(Sukendar, Fatmawati, & Frinzani, 2021)
		Fulfillment of delivery time change request		
	Responsiveness	Supplier responds well to customer complaints		(Pramita & Wirawan, 2019)
		Supplier responds to changes the delivery schedule		(Sukendar, Fatmawati, & Frinzani, 2021)

The use of data used in this research is in the form of primary data obtained from interviews and questionnaire results. This interview method was carried out with Senior Procurement Buyer, Purchasing Staff and Supply Chain Staff. The distribution of paired comparison questionnaires given to 6 (six) respondents including: Assistant Procurement Manager, Purchasing Staff, Upstream Flow Supervisor, Supply Chain Staff, Supplier Quality Engineer Leader and Supplier Quality Engineer Staff. A pairwise comparison rating scale consisting of 1 to 9, was used in the questionnaire as an instrument for measuring respondents' answers.

In this study, the number of samples was determined based on purposive sampling technique. Meanwhile, the definition of purposive sampling technique according to [14] is the stage of determining the sample according to their expertise, as long as the informant / respondent who has been determined as a sample has qualified as an expert who really understands the problem at hand, then it is appropriate to be used as a research sample.

In this study, the researchers used a judgement sampling technique based on the characteristics had been specified, which is Employees of PT ABC who are directly involved in the packing box supplier activities and have insights into the performance of the packing box suppliers. The object of this research is the packing box supplier at ABC company which consists of supplier X, supplier Y and supplier Z.
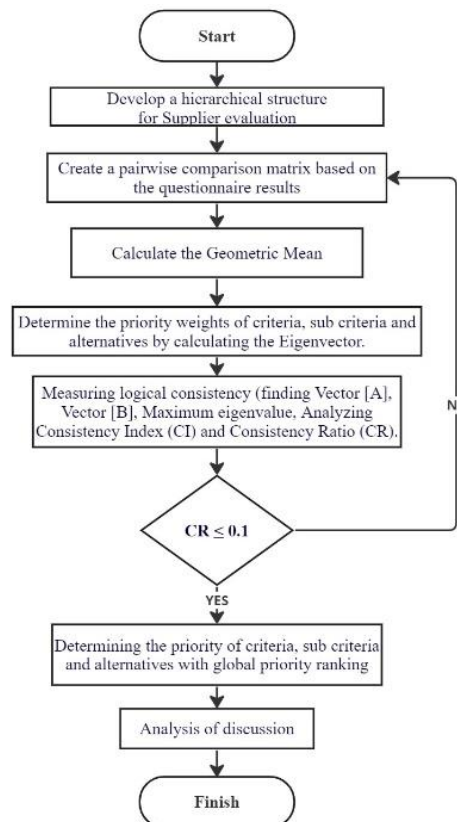
Figure 1. Data analysis technique

The data analysis technique used as decision making in the supplier performance assessment process is the Analytical Hierarchy Process (AHP) method designed by Prof. Thomas L. Saaty in 1970, by going through several stages of the data analysis process using the Microsoft Excel application. The stages in the process of evaluating the performance of packing box suppliers at ABC company using the Analytical Hierarchy Process (AHP) method are as follows:

1. Structuring the hierarchy of problems
2. Making a pairwise comparison matrix between criteria, between sub criteria and alternatives

3. Develop a pairwise comparison rating scale that is set to assess the importance of each element:

Table 3. Comparison rating scale

Importance Intensity	Definition
1	Equally important
3	Slightly more important
5	More important
7	Highly important
9	Definitely more important
2,4,6,8	Middle value

4. Based on the assessment by the respondents, it will be averaged using the geometric mean, to obtain one result in the pairwise comparison matrix, using the following formula:

$$GM = \sqrt[n]{(X_1)(X_2) \dots (X_n)} \qquad (1)$$

5. Determine the priority weight (eigenvector)
   a. Divide each value in a column of the pairwise comparison matrix by the total of the corresponding column.
   b. Sum the results on each row of the pairwise comparison matrix
   c. Divide the sum result by the number of criteria/sub criteria used.

6. Perform consistency measurement (λ Max)
   a. Find the value of Vector [A]: The initial matrix is multiplied by the priority weight (eigenvector).
   b. Find the value of Vector [B]

$$B = \frac{Vector\ [A]}{Weight\ of\ priority} \qquad (2)$$

   c. Finding the Maximum Eigenvalue

$$\lambda\ maks\ = \frac{Total\ elements\ in\ Vector\ B}{n} \qquad (3)$$

7. Calculate Consistency Index (CI)

$$CI = \frac{\lambda\ maks\ -\ n}{n-1} \qquad (4)$$

8. Determine the Random Index (RI) according to the number of criteria / sub criteria used

Table 4. Random Index (RI)

N	1	2	3	4	5	6	7	8	9	10
RI	0	0	0,58	0,90	1,12	1,24	1,32	1,41	1,45	1,49

9. Calculate Consistency Ratio (CR)

$$CR = \frac{CI}{RI} \qquad (5)$$

If the resulting Consistency Ratio ≤ 0.1, it can be concluded that the data obtained is consistent and if the resulting Consistency Ratio ≥ 0.1, the questionnaire needs to be redistributed and improve the comparison matrix made.

10. Determine the priority weight (eigenvector) between sub-criteria on each criterion.
11. Determining the priority weight (eigenvector) between alternatives (suppliers) that are compared against each sub-criteria

12. After the weight of each criterion, sub-criteria and alternative (supplier) is obtained, a synthesis will be carried out to determine the global priority of each level. To determine the global priority, it can be done by multiplying the local priority criteria and local priority sub criteria.

4 Results and Discussion

4.1 Hierarchical Structure

The hierarchical structure in this study consists of the top level which is the purpose of the research, namely the evaluation of the performance of packing box suppliers. Followed by the first level which is each assessment criteria used. Then, level 2 is the sub-criteria of each criterion, and at the last level is an alternative (supplier) consisting of the names of packing box suppliers.
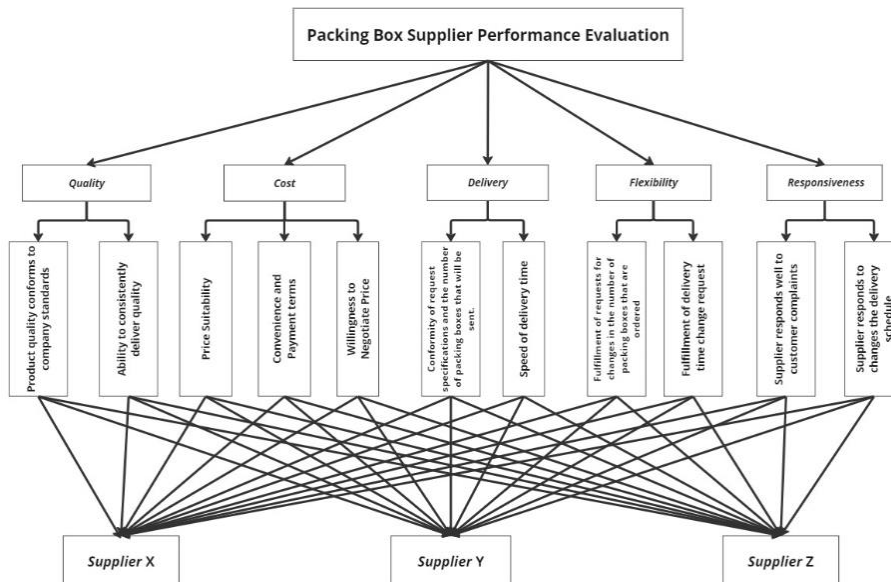

Figure 2. Hierarchical Structure

4.2 Calculation of the weight (local priority) of each criterion

The method of calculating weights / priorities (eigenvector) is obtained based on distributing questionnaires to 6 (six) respondents. After the questionnaire assessment process has been filled in by each respondent, data management will be carried out and obtain 3 (three) results of pairwise value comparison (criteria, sub criteria and alternatives / suppliers) by each respondent.

In this case, the implementation of the AHP method only relies on one answer in the comparison matrix, so the next stage needs to calculate the average using the geometric mean.

Table 5. Geomean Results

Criteria	Quality	Cost	Delivery	Flexibility	Responsiveness
Quality	1,00	8,36	2,33	5,73	5,87
Cost	0,12	1,00	0,23	0,20	0,28
Delivery	0,43	4,43	1,00	1,31	3,90
Flexibility	0,17	5,10	0,76	1,00	3,23
Responsiveness	0,17	3,62	0,26	0,31	1,00

Through the pairwise comparison matrix calculation table that has been made, it produces the following criteria priority weights:

Table 6. Eigenvector Results

Criteria	Quality	Cost	Delivery	Flexibility	Responsiveness	Total	Weight of Priority	Rank
Quality	0,53	0,37	0,51	0,67	0,41	2,49	0,50	1
Cost	0,06	0,04	0,05	0,02	0,02	0,20	0,04	5
Delivery	0,23	0,20	0,22	0,15	0,27	1,07	0,21	2
Flexibility	0,09	0,23	0,17	0,12	0,23	0,83	0,17	3
Responsiveness	0,09	0,16	0,06	0,04	0,07	0,41	0,08	4
Total	1,00	1,00	1,00	1,00	1,00	5,00	1,00	

After producing the criteria weights, it can be continued by doing the same calculations on sub criteria and alternatives (suppliers). Then it will be able to produce a global priority calculation for each level as follows:

Table 7. Global prioritization results

Kriteria (Level 1)	Sub Criteria (Level 2)	Global Priority	Alternatives (Supplier)	Local Priority	Global Priority
Quality 0,50	Q1 0,39	0,195	Supplier X	0,07	0,014
			Supplier Y	0,32	0,062
			Supplier Z	0,61	0,119
	Q2 0,61	0,305	Supplier X	0,14	0,043
			Supplier Y	0,33	0,101
			Supplier Z	0,54	0,165
Cost 0,04	C1 0,67	0,027	Supplier X	0,1	0,003
			Supplier Y	0,32	0,009
			Supplier Z	0,58	0,016
	C2 0,09	0,004	Supplier X	0,12	0,000
			Supplier Y	0,32	0,001
			Supplier Z	0,56	0,002
	C3 0,23	0,009	Supplier X	0,12	0,001
			Supplier Y	0,34	0,003
			Supplier Z	0,53	0,005
Delivery 0,21	D1 0,21	0,044	Supplier X	0,1	0,004
			Supplier Y	0,25	0,011
			Supplier Z	0,65	0,029
	D2 0,79	0,166	Supplier X	0,12	0,020
			Supplier Y	0,27	0,045
			Supplier Z	0,61	0,101
Flexibility 0,17	F1 0,17	0,029	Supplier X	0,09	0,003
			Supplier Y	0,27	0,008
			Supplier Z	0,63	0,018
	F2 0,83	0,141	Supplier X	0,14	0,020
			Supplier Y	0,27	0,038
			Supplier Z	0,59	0,083
Responsiveness 0,08	R1 0,35	0,028	Supplier X	0,13	0,004
			Supplier Y	0,32	0,009
			Supplier Z	0,54	0,015
	R2 0,65	0,052	Supplier X	0,09	0,005
			Supplier Y	0,35	0,018
			Supplier Z	0,56	0,029

If you have obtained a global priority, you can continue by summing up each weight value on each alternative to the global priority. Then the results of the overall calculation of alternative weights (suppliers) are in the following table:

Table 8. Supplier Prioritization Results

Alternatives (Supplier)	Global Priority	Rank
Supplier X	0,116	3
Supplier Y	0,305	2
Supplier Z	0,582	1

With regard to the outcomes of the evaluation of supplier performance, an analysis of each employed criterion reveals the following findings as presented in the subsequent table:

Table 9. Alternative Prioritization

Criteria	Supplier X	Supplier Y	Supplier Z
Quality	0,056	0,163	0,284
Cost	0,004	0,013	0,022
Delivery	0,024	0,056	0,130
Flexibility	0,022	0,046	0,101
Responsiveness	0,008	0,027	0,044
Total	0,116	0,305	0,582

The value in the pairwise comparison matrix of criteria can be declared consistent if the CR result is less than 0.1. However, if the CR result is more than 0.1 then the pairwise comparison assessment on the criteria matrix is declared inconsistent. If the results are inconsistent, then filling in the values in the pairwise matrix on criteria, sub criteria & alternatives needs to be repeated. The following data is the result of measuring the Consistency Ratio (CR) of respondents' assessments of the evaluation of packing box suppliers:

Table 10. Consistency

Pairwise Comparisons	CR	Remarks
Inter Criteria	0,06	Consistent
Inter-Sub Criteria quality	0,00	Consistent
Inter-Sub Criteria cost	0,06	Consistent
Inter-Sub Criteria delivery	0,00	Consistent
Inter-Sub Criteria flexibility	0,00	Consistent
Inter-Sub Criteria responsiveness	0,00	Consistent
Between alternatives to sub-criteria Q1	0,05	Consistent
Between alternatives to sub-criteria Q2	0,08	Consistent
Between alternatives to sub-criteria C1	0,06	Consistent
Between alternatives to sub-criteria C2	0,07	Consistent
Between alternatives to sub-criteria C3	0,04	Consistent
Between alternatives to sub-criteria D1	0,05	Consistent
Between alternatives to sub-criteria D2	0,04	Consistent
Between alternatives to sub-criteria F1	0,03	Consistent
Between alternatives to sub-criteria F2	0,07	Consistent
Between alternatives to sub-criteria R1	0,06	Consistent
Between alternatives to sub-criteria R2	0,04	Consistent

Referring to the results of the Analytical Hierarchy Process (AHP) analysis that has been carried out at ABC Company at **Table 7,** it is known that the most influential criteria for evaluating supplier packing box activities are quality criteria with a weight of 0.50. Then, the next criteria that influence the evaluation of packing box suppliers are the delivery criteria with a weight of 0.21. Flexibility criteria with a total weight of 0.17; and responsiveness criteria with a weight of 0.08 and the last priority is the cost criteria with a weight value of 0.04.

Based on the weight of the quality criteria, it shows that ABC Company in the process of evaluating suppliers is very concerned about the best quality of the packing box to be used. Through the results of this study, it shows that there is harmony between current research and previous research, which is based on research from [15] [16] [17] [2] [11] [18] [19] It is evident that the Quality criteria carries the greatest significance in the assessment of supplier performance. This prominence stems from the fact that the quality of the supplier's product or service directly influences both customer satisfaction and the reputation of the company. The quality criteria have sub-criteria which include 2 (two) sub-criteria along with their respective weights including product quality in accordance with company standards (Q1) with a weight of 0.39; and the ability to provide quality consistently (Q2) with a weight of 0.61.

In this study, 3 (three) sub-criteria that have an influence on the supplier evaluation process are the ability to provide consistent quality (Q2) with a weight of 0.305; sub criteria Product quality in accordance with company standards (Q1) with a weight of 0.195; sub criteria Delivery time speed (D2) with a weight of 0.166. Meanwhile, in research [15] 3 (three) sub-criteria that have a significant effect on supplier evaluation activities are Product Quality in accordance with company standards with a weight of 0.900, Delivery Time Speed with a

weight of 0.900, and sub-criteria Can Handle Customer Complaints Well with a weight of 0.896.

Based on the results of the calculation of supplier performance evaluation in all criteria and sub criteria, it is known that Supplier Z is the first priority supplier that excels in all criteria and sub criteria, which can be a consideration so that Supplier Z can be maintained as a supplier in the long term. Through this calculation, it is also known that the second position is occupied by Supplier Y and the lowest position is occupied by Supplier X, which in this calculation shows that there is a need to improve the performance of the two suppliers from each criterion and sub-criteria.

5 Conclusion

In alignment with the research goals and findings concerning the establishment of Vendor Performance Indicator (VPI) criteria through the application of the Analytical Hierarchy Process (AHP) technique for evaluating ABC company's packaging box supplier, it can be inferred that the criteria exerting a substantial impact on the assessment of supplier performance, leading to the highest weight value, pertain to quality with a weight of 0.50. In contrast, the criteria bearing the least weight are associated with cost considerations, possessing a weight of 0.04.

Through the calculation of global priority, it becomes evident that within the evaluation procedure for packaging box suppliers' performance, the sub-criterion attaining the greatest weight is linked to the capability of ensuring consistent quality (Q2) with a weight of 0.609. Conversely, the sub-criterion associated with the ease and timing of payment (C2) garners the lowest weight, amounting to 0.006.
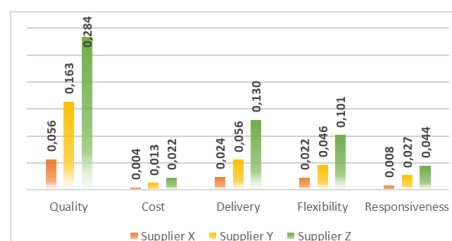
Figure 3. Alternative Prioritization

Through calculations carried out as a whole on alternative weights for each criterion, that in the quality criteria the highest weight value is achieved by Supplier Z by obtaining a weight of 0.284. Meanwhile, the lowest weight was achieved by Supplier X with a weight of 0.056. In the cost criteria, the maximum weight value is obtained by Supplier Z with the highest weight of 0.022. Meanwhile, suppliers who have the minimum value in the cost criteria are Supplier X with a weight of 0.004. Furthermore, in the delivery criteria, the top weight value is obtained by Supplier Z by getting a weight of 0.130. Then, the lowest weight is owned by Supplier X by obtaining a weight of 0.024. In the flexibility criteria, the top weight is owned by Supplier Z by achieving a weight of 0.101. Meanwhile, Supplier X received a weight of 0.022 as the lowest weight. Then, the responsiveness criteria obtained the maximum performance weight value obtained by Supplier Z by getting a weight of 0.044; while the supplier who got the minimum value was obtained by Supplier X by obtaining a weight of 0.008.

Analyzing the comprehensive computation outcomes for every level of criteria and sub-criteria in the assessment of packing box suppliers' performance, it is evident that Supplier Z

emerges as the top-performing supplier with an aggregate weight of 0.582. It is recommended to retain Supplier Z as a long-term supplier due to its outstanding performance in contrast to the other two suppliers. The second priority supplier is Supplier Y with an overall weight of 0.305; and the last priority is Supplier X by obtaining an overall value of 0.116.

6 Suggestion

Referring to the results of the assessment and conclusions above, the researcher provides recommendations for companies and related parties, namely:
1. In order for the packing box supplier evaluation process to run effectively, companies should consider using the supplier performance assessment form using the Analytical Hierarchy Process (AHP) method as a supporting method in measuring the performance of each supplier and can combine the criteria that are considered relevant in supporting the packing box supplier evaluation process. Since the conducted research indicates, this approach has the capability to effectively evaluate the performance of individual suppliers by assigning weights to the criteria and sub-criteria of their performance.
2. Then based on the research conducted, Supplier Z obtained the highest weight of all criteria and sub criteria, through this the company can maintain cooperation and can make supplier Z a partner in the long term. Regarding suppliers X and Y who get lower weights, it is necessary to monitor and make the necessary improvements to optimize performance and achieve maximum results.
3. For future researchers, it is hoped that they can develop a wider range of criteria and sub-criteria to be used, so that the description of the performance of each supplier can be described more specifically and thoroughly.

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