Jurnal Teknik Industri, Vol. 23, No. 2, December 2021
ISSN 1411-2485 print / ISSN 2087-7439 online
DOI: 10.9744/jti.23.2.129-138

An Analytical Network Process for Selecting Raw Material Suppliers of UNP100: a Case Study

Kirana Rukmayuninda Ririh[1*], Desinta Rahayu Ningtyas[2], Fikri Taufiq Rahman[3]

Abstract: A UNP-100 is a canal iron that connects the storage area (bin) to the frame of a truck. Therefore, the selection of UNP-100 suppliers is an essential process. Suppliers are chosen to provide high-quality materials, in-time deliveries, affordable prices, and excellent services, the applied analytical network process (ANP) in this study. The quantitative method is conducted through questionnaires, and the qualitative method is by interviews. After distributing the questionnaires, calculations are carried out to assess suppliers by constructing an ANP supermatrix. The respondents are the purchasing managers, the quality managers, and the PPIC managers. The criteria to choose suitable suppliers are packaging (0.060), price (0.212), customer care (0.712), delivery (0.103), and quality (0.351). The prioritized UNP-100 suppliers are PT. KPPE (0.346), PT. KPS (0.344), and PT. SME (0.31).

Keywords: Supplier selection, analytical network process, supermatrix, decision making.

Introduction

Supplier selection is an essential part of supply chain management. Choosing the right supplier determines the sound quality of goods supplied, affordable prices, efficient time management, better service from suppliers, and many more [1]. In addition, the selection of suppliers also determines the performance and consistency of the company for remaining optimal and able to compete in the market [2]. PT. Tass Engineering is a truck-body company that makes various dump trucks. In the production of dump trucks, the raw material with a vital role is UNP iron 100 (UNP is the name for the U Channel standard). It functions as a connector between the storage area (bin) and a truck's frame. The profile size of the UNP-100 affects the momentum of the storage area (bin).

To supply raw materials for UNP-100, PT. Tass Engineering collaborates with three permanent suppliers, which are PT.KPPE, PT.KPS, and PT SME. PT. Tass Engineering chooses suppliers based on the criteria of quality, arrival time, costs, and others.

Various well-known selection methods are used in decision-making in several studies, such as the analytical hierarchy process (AHP), TOPSIS, hybrid multi-criteria decision-making, and many more [3-8].

[1] Faculty of Engineering, Department of Industrial Engineering, Universitas Pancasila, Jl. Raya LentengAgung, 56-80, Srengseng Sawah, Jakarta Selatan, 12640, Indonesia.

Email: kirana.ririh@univpancasila.ac.id, desinta@univpancasila.ac.id, fikritaufiq21@gmail.com

* Corresponding author

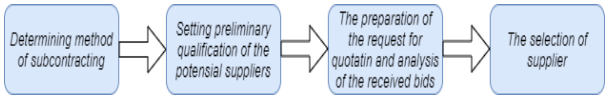

Figure 1. Supplier selection process [4]

The process to select a supplier is depicted in Figure 1.

The ANP method applies an integrated approach to assign weights to criteria and suppliers rank. ANP is also used to determine supplier ratings. ANP is an extension of the analytic hierarchy process (AHP) in decision making that involves determining work relationships, making judgments on the relative importance of element pairs, and synthesizing results [9-10].

A hierarchy does not represent the relationship between levels in AHP. This shortcoming is removed in the ANP feedback approach. In AHP, the importance of criterion determines the importance of alternatives but does not represent the importance of the alternative. This could affect the importance of criterion [11]. Therefore, the linear structure from top to bottom does not apply to complex systems. The advantage of ANP over AHP is the ability to solve problems where alternatives and criteria have interactions that cannot be displayed in a hierarchy. An ANP network contains the clusters (components, nodes, or criteria) and elements (sub-criteria) within the cluster. The node element can bring influence some or all the other elements. The advantage of using ANP is the holistic approach and estimation to incorporate all the primary factors and principles that play a role in the decision-making process and assessing the relationship between criteria and sub-criteria [9, 12-14]. Thus, this study applies ANP for supplier selection.

Table 1. Criteria-subcriteria for UNP-100 supplier selection

Criteria	Definition	Subcriteria	References
The packaging on raw materials	The method and appearance of the package to be seen as clean or tidy and safe.	• Tidy packaging • The convenience of removing and installing parts • No damage to the received materials	[15,16]
Price	Price can determine how much the company should spend when it needs to trace the price of an offer.	• Interestingly accumulated discounts • Affordable raw material prices • Simple payment process and procedures	[17,18]
Customer care	Service to the customer can affect the clarity of communication between supplier and customer (company)	• Details of product information • Responsive to customer voice or complaints • Good attitude while serving the customers	[19-21]
Delivery	Transporting the orders from supplier to customer (company) in timely manner and precisely fit the requirement	• In time delivery • Low delivery cost • Delivery lot size as demanded	[22-24]
Quality	Quality determines how well suppliers carry out certain activities.	• Precise size of profile raw materials • Surface cleanliness of raw materials • Minimum number of raw materials with "Not Good" label in "Incoming" Status	[25,26]

This study examines several criteria such as packaging, price, customer care, delivery, and quality. Each criterion is adopted from previous case studies. There are some sub-criteria within criteria, as described in Table 1.

This study aims to identify the most significant factors that affect UNP-100 supplier selection and design a strategic procurement system related to supplier criteria to achieve high-quality raw material UNP-100.

Methods

This section first discusses a brief explanation of data collecting. Comprehensive steps to process the data until extract to the conclusion are explained.

Data Collection

Qualitative and quantitative approaches are applied. This study initiates with interviews and field observation. Meanwhile, in the quantitative method, data were gathered through three-step questionnaires of pairwise comparison, Saaty's nine-point absolute scale to obtain the decision maker's preferences. The first section of the questionnaire contains the scoring of the importance value of each criterion. The second section of the questionnaires is used to calculate each criterion's interdependencies, sub-criteria, and indicators. Finally, the third section of the questionnaire is utilized to examine the pairwise comparison between sub-criteria to determine each category's weight. Respondents were chosen from managing directors: purchasing, quality, and PPIC managers. In this study, the software Super Decision was used to support the ANP analysis.

The ANP Supplier Selection Measurement Framework

Step 1: Model Construction
The model construction is based on the problem formulation in the first phase of the ANP methodology. ANP organizes decision-making problems into a network of clusters, nodes, and dependencies between criteria and sub-criteria [5] (see Figure 2).

Step 2: Building Pairwise Comparison Matrices
In this step, a pairwise comparison matrix is developed. Then, the relationships between clusters and nodes in the network are examined. Finally, the network structure is constructed.

The respondents were asked to rate each criterion and alternative using the Saaty scale (Table 2). Then the relative weights are calculated using the geometric mean, and the relative weights of each level's elements are estimated [27]. Finally, the consistency ratios (CR) were checked. The acceptable CR is less than 0.10.

The CR is formulated as

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

While RI is the random index (Table 3).

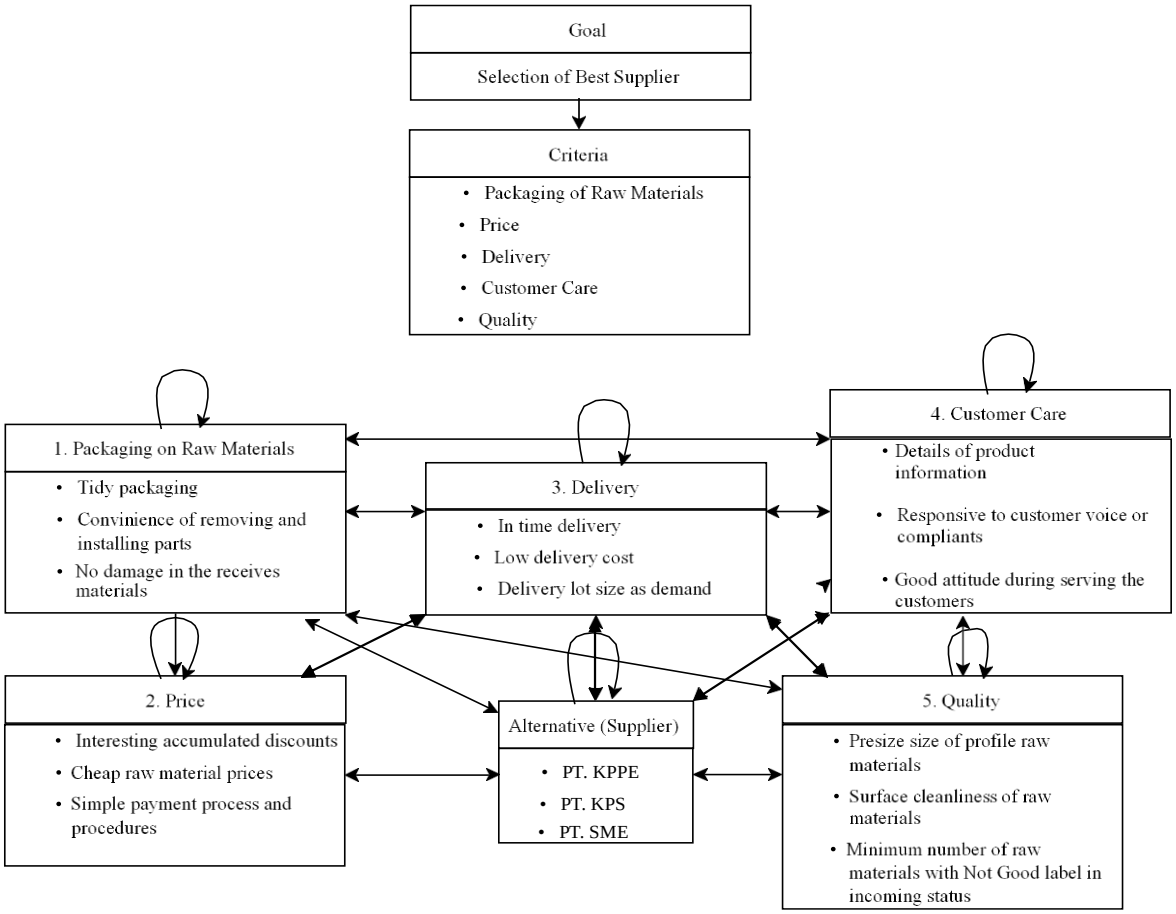

Figure 2. UNP-100 supplier selection framework

The consistency Index (CI) is formulated as

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

While λmax is the largest eigenvalue, and the n is the number of criteria or sub-criteria of each level [28].

Step 3: Supermatrix Formation and Overall Priority Calculation

Table 2. Pairwise Comparison Scale for ANP

Intensity of judgment	Numerical rating
Extreme importance	9
Very strong importance	7
Strong importance	5
Moderate importance	3
Equal importance	1
For compromise between the above values	2,4,6,8

Table 3. Consistency ratio random number index

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.51

The third step in the ANP methodology is creating a supermatrix that contains all the network's interactions between clusters and nodes.

Step 4: Prioritization and selection

Table 4. Pairwise comparison criteria for supplier selection

Criteria	λmax	Consistency index	Consistency ratio
1. Packaging	3.065	0.033	0.056
2. Price	3.065	0.033	0.056
3. Delivery	3.07	0.035	0.061
4. Customer care	3.111	0.055	0.095
5. Quality	3.113	0.057	0.097

Results and Discussion

The car body industry has become a vital sector in transportation, where many vehicles have been modified to meet human needs. Dump trucks are among the most needed vehicle modifications in the car body industry because they simplify and shorten the transfer of goods carried by the dump truck. With many dumps truck orders, the production function in the company must also be more controllable, considering that orders are increasing.

For now, price and quality are the main concerns, especially for raw materials. The raw materials needed are now a general topic of discussion in production planning, purchasing, and using suitable

raw materials, which will minimize problems. This problem considers the costs where the price of raw materials is low and has more discounts. In addition, choosing quality raw materials will also improve the quality of the products by considering the more precise size of the raw materials and the large number of raw materials that are suitable for use. Unlike Arvidsson and Melander [14], the price is critical for mass production automotive manufacturing. In some instances, the number of raw materials that are not suitable for use will affect the cost of replacing new raw materials and reduce the quality ([10,29,30]). Therefore, the production control plan needs to be reviewed, one of which is choosing the right supplier to solve problems with these raw materials. This study will undoubtedly be helpful for companies and can be developed as new problems emerge.

ANP is one of the multi-criteria decision-making methods that applied in the last two decades. It results in a supermatrix and involves pairwise comparison.

The pairwise comparison is applied for each criterion, including packaging, price, delivery, customer care, and quality (see Table 4).

Table 5 shows the paired comparisons that display the degree of criteria on every criterion. The more significant the criteria's priority weight, the greater is the influence on a criterion. The price is mainly influenced by the quality criterion with a priority weight of 0.663. The quality is most influenced by delivery with a priority weight of 0.562. Moreover, the consistency ratio results of all comparisons in Table 5 do not reach 0.10. Thus, all elements of measurement are valid.

Further, a comparison of the influence magnitude between sub-criteria is calculated. This comparison can be seen in Table 6, which is divided into three tables.

Table 6a shows that the subcriterion "Simple payment processes and procedures" is most affected by subcriterion "Responsive to customer voice or complaints" with a priority weight of 0.525. The CR is 0.027, which is less than 0.1. Thus, the pairwise comparisons are consistent.

Table 6b shows that the subcriterion "Minimum amount of raw material with Not Good label in the entry status" is most affected by "No damage in the receives materials." Its priority weight is 0.063, and the consistency ratio is 0.01.

Table 6c shows that subcriterion "Size precision of profile raw material" is most affected by "No damage in the receives material" with the priority weight of 0.452. The CR is 0.05, and thus it is consistent.

Overall, the unweighted supermatrix of intercriteria shows paired comparisons of influences of sub-criteria on a sub-criteria; the more significant the priority weight, the greater the influence. For example, sub-criteria "Simple payment processes" and "Procedures" are more influenced by the subcriterion "Responsive to customer's voice or compliant" with a priority weight of 0.525. The subcriterion "Minimum amount of raw material with the wrong label in entry status" is most affected by the subcriterion "No damage to the material received" with a priority weight of 0.343. The subcriterion "Size precision of profile raw material" is most affected by the "No damage to the material received" with a priority weight of 0.37. The elements of measurement in the criteria are valid with the consistency ratio are less than 0.10.

Table 7 shows the paired performance comparisons from multiple suppliers by sub-criteria; the greater the priority weight, the greater the performance. The consistency ratio results of all comparisons in Table 7 are less than 0.10, which shows that all measurement elements are valid. It shows that PT. KPS dominated the other companies with the highest score in every subcriterion, which meant PT. KPS is the most favorable company to choose

Furthermore, Table 8 shows the comparison of pairs between existing criteria. The greater the priority weight, the more influence the criteria have on determining supplier selection. As a result, the quality criteria affect more to supplier selection, and all the measurement elements are valid.

Table 9 shows the comparison of pairs between sub-criteria in a criterion. All sub-criteria have a consistency ratio of less than 0.10, which means they are good measurements. Calculation in Table 9 shows the rank for each sub-criteria. They showed that the packaging of raw material criteria-sub-criteria has an adequate consistency ratio (0.056), but it eventually goes to the least prioritized in Table 10. Meanwhile, the sub-criteria of the quality criteria has the weakest consistency ratio (0.097). The final results depicted in Table 10 showed the strongest aspect of considerations when choosing the suppliers.

Table 7. Unweightedsupermatrix of supplier's performance for each subcriteria.

Tidy packaging	PT. KPPE	PT. SME	PT. KPS	CI = 0.044 CR = 0.012 Priority weight
PT. KPPE	0.150	0.145	0.153	0.149
PT. SME	0.313	0.303	0.300	0.305
PT. KPS	0.537	0.553	0.547	0.546
No damage to the receives materials	PT. KPPE	PT. SME	PT. KPS	CI = 0.002 CR = 0.004 Priority weight
PT. KPPE	0.371	0.351	0.398	0.373
PT. SME	0.372	0.352	0.326	0.350
PT. KPS	0.257	0.298	0.276	0.277
Interesting accumulated discounts	PT. KPPE	PT. SME	PT. KPS	CI = 0.078 CR = 0.045 Priority weight
PT. KPPE	0.642	0.646	0.638	0.642
PT. SME	0.164	0.165	0.168	0.166
PT. KPS	0.194	0.189	0.193	0.192
Simple payment process and procedures	PT. KPPE	PT. SME	PT. KPS	CI = 0.033 CR = 0.009 Priority weight
PT. KPPE	0.722	0.650	0.145	0.642
PT. SME	0.128	0.178	0.666	0.166
PT. KPS	0.150	0.172	0.188	0.192
Affordable raw material prices	PT. KPPE	PT. SME	PT. KPS	CI = 0.019 CR = 0.007 Priority weight
PT. KPPE	0.138	0.141	0.134	0.138
PT. SME	0.543	0.554	0.559	0.552
PT. KPS	0.318	0.305	0.308	0.310
In time delivery	PT. KPPE	PT. SME	PT. KPS	CI = 0.050 CR = 0.086 Priority weight
PT. KPPE	0.108	0.061	0.142	0.104
PT. SME	0.388	0.217	0.199	0.268
PT. KPS	0.504	0.722	0.660	0.628
Low delivery cost	PT. KPPE	PT. SME	PT. KPS	CI = 0.003 CR = 0.005 Priority weight
PT. KPPE	0.483	0.524	0.467	0.491
PT. SME	0.133	0.144	0.162	0.146
PT. KPS	0.384	0.332	0.372	0.363
Delivery lot size as demand	PT. KPPE	PT. SME	PT. KPS	CI = 0.007 CR = 0.013 Priority weight
PT. KPPE	0.537	0.599	0.509	0.548
PT. SME	0.125	0.139	0.170	0.145
PT. KPS	0.338	0.262	0.321	0.307
Details of product information	PT. KPPE	PT. SME	PT. KPS	CI = 0.003 CR = 0.005 Priority weight
PT. KPPE	0.152	0.168	0.138	0.153
PT. SME	0.376	0.416	0.431	0.407
PT. KPS	0.473	0.416	0.431	0.440
Responsive to customer voice or complaints	PT. KPPE	PT. SME	PT. KPS	CI = 0.043 CR = 0.074 Priority weight
PT. KPPE	0.611	0.476	0.685	0.591
PT. SME	0.185	0.144	0.087	0.139
PT. KPS	0.204	0.380	0.228	0.271
Size precision of the profile raw materials	PT. KPPE	PT. SME	PT. KPS	CI = 0.036 CR = 0.062 Priority weight
PT. KPPE	0.132	0.091	0.388	0.104
PT. SME	0.396	0.227	0.236	0.283
PT. KPS	0.453	0.742	0.376	0.612
Minimum number of raw materials with Not Good label in incoming status	PT. KPPE	PT. SME	PT. KPS	CI = 0.002 CR = 0.004 Priority weight
PT. KPPE	0.132	0.118	0.141	0.131
PT. SME	0.349	0.312	0.304	0.322
PT. KPS	0.519	0.570	0.555	0.548

Table 8. Pairwise comparison of relation between inter-criteria

	Customer care	Price	Quality	Packaging	Delivery	CI = 0.536 CR = 0.062 Priority weight
Customer care	0.134	0.344	0.133	0.148	0.181	0.188
Price	0.041	0.104	0.133	0.148	0.212	0.128
Quality	0.669	0.439	0.563	0.448	0.447	0.513
Packaging	0.585	0.061	0.058	0.087	0.054	0.169
Delivery	0.585	0.052	0.133	0.169	0.106	0.209

Table 9. Pairwise comparison of three subcriteria in one criterion.

Price	Size precision of the profile raw materials	Interesting, accumulated discounts	Affordable raw material prices	CI = 0.047 CR = 0.081 Priority weight
Size precision of the profile raw materials	0.190	0.341	0.173	0.235
Interesting, accumulated discounts	0.066	0.118	0.149	0.111
Affordable raw material prices	0.744	0.540	0.678	0.654
Delivery	In time delivery	Low delivery cost	Delivery lot size as demand	CI = 0.035 CR = 0.061 Priority weight
In time delivery	0.258	0.409	0.239	0.302
Low delivery cost	0.066	0.105	0.135	0.102
Delivery lot size as demand	0.677	0.486	0.627	0.596
Customer Care	In time delivery	Low delivery cost	Delivery lot size as demand	CI = 0.055 CR = 0.095 Priority weight
Details of product information	0.176	0.158	0.334	0.223
Responsive to customer voice or complaints	0.757	0.681	0.538	0.659
Good attitude while serving the customers	0.067	0.161	0.128	0.119
Quality	The precise size of profile raw materials	Surface cleanliness of raw materials	Minimum number of raw materials with Not Good label in incoming status	CI = 0.057 CR = 0.097 Priority weight
Size precision of the profile raw materials	0.259	0.455	0.235	0.316
Surface cleanliness of raw materials	0.060	0.106	0.148	0.105
Minimum number of raw materials with Not Good label in incoming status	0.681	0.440	0.617	0.579
Packaging of Raw Material	The precise size of profile raw materials	Surface cleanliness of raw materials	Minimum number of raw materials with Not Good label in incoming status	CI = 0.033 CR = 0.056 Priority weight
Tidy packaging	0.114	0.135	0.068	0.106
The convenience of removing and installing parts	0.588	0.699	0.753	0.680
No damage to the receives materials	0.298	0.166	0.179	0.214

Table 10. Ranking of UNP-100 supplier criteria and subcriteria based on ANP weights

Criteria	Subcriteria	Criteria Weights	Subcriteria Weights	Criteria Ranking	Subcriteria Ranking
Packaging on raw materials	-Tidy packaging	0.069	0.015	13	5
	-Convenience of removing and installing parts		0.042	14	
	-No damage to the receives materials		0.012	9	
Price	-Size precision of the profile raw materials	0.212	0.067	7	2
	-Cheap raw material price		0.077	5	
	-Simple payment process and procedures		0.068	6	
Customer care	-Details of product information	0.172	0.083	3	3
	-Responsive to customer voice or complaints		0.081	4	
	-Good attitude while serving the customers		0.008	15	
Delivery	-In time delivery	0.103	0.035	7	4
	-Low delivery cost		0.030	5	
	-Delivery lot size as demand		0.038	6	
Quality	-Size precision of the profile raw materials	0.351	0.046	8	1
	-Surface cleanliness of raw materials		0.146	2	
	-Minimum number of raw materials with Not Good label in incoming status		0.159	1	

Table 11. Suppliers Rank from Limit Supermatrix Alternatives

Alternative	Limit Supermatrix	Normalized Limit Supermatrix	Ranking
PT. KPPE	0.033	0.353	2
PT.KPS	0.036	0.381	1
PT.SME	0.025	0.266	3

Here are the priorities.

Icon	Name	Normalized by Cluster	Limiting
No Icon	PT. KPPE	0.35295	0.033125
No Icon	PT.KPS	0.38069	0.035728
No Icon	PT.SME	0.26636	0.024998
No Icon	Details of product information	0.47983	0.082530
No Icon	Responsive to customer voice or compliants	0.46936	0.080729
No Icon	Good attitude during serving the customers	0.05080	0.008738
No Icon	Interesting accumulated discounts	0.31507	0.066597
No Icon	Cheap raw material price	0.36203	0.076524
No Icon	Simple payment process and procedures	0.32290	0.068251
No Icon	Surface cleanliness of raw materials	0.12997	0.045611
No Icon	Minimum number of raw materials with Not Good ~	0.45338	0.159112
No Icon	Size precision of profile raw materials	0.41665	0.146221
No Icon	Tidy Packaging	0.22190	0.015318
No Icon	Convernience of removing and installing parts	0.16990	0.011728
No Icon	No damage in the receives materials	0.60820	0.041984
No Icon	Low delivery cost	0.34368	0.035333
No Icon	Delivery lot size as demand	0.29140	0.029958
No Icon	In time delivery	0.36492	0.037516

Figure 3. The priority value for choosing the best supplier

Table 10 and Table 11 present the overall results of the calculations. In this study, there are five criteria and fifteen sub-criteria. Each weight the of criteria are as follows: 0.069 (packaging), 0.212 (price), 0.172 (customer care), 0.103 (delivery), and 0.351 (quality). The two most important criteria are quality (0.351) and price (0.212) (Table 10). For the quality criteria, the surface cleanliness of raw materials should have the most attention. Meanwhile, for the price criteria, the surface cleanliness of raw materials is the most prioritized aspect. In the overall sub-criteria, there are five top sub-criteria involved in the decision making, such as surface cleanliness of raw materials (0.159), a minimum number of raw materials with NG label in incoming status (0.146), details of product information ((0.083), responsive to customer voice or complaints (0.081), and affordable raw material price (0.077). According to Table 11, the overall ranks of the supplier are PT. KPS (0.381), PT. KPPE (0.353), and PT. SME (0.266).

Sensitivity Analysis

Super Decisions software is used to analyze sensitivity to specific sub-criteria in an ANP model. There are five criteria from the study results: quality, price, customer care, packaging of raw materials, and shipping. Regarding priorities for the five criteria, quality has the highest priority (0.351) than the other four criteria. This means quality will significantly affect one of the alternative solutions if the priority value of the criteria is changed. The sub-criteria that significantly affects the quality is 'minimum number of raw materials with Not Good label in incoming status' (0.159) because it has the greatest priority in the criteria. This test shows that changing the value of criteria weights on the tested alternatives affects the actual ranking results.

In addition, globally, the priority values of these sub-criteria are also at the highest of all existing sub-criteria. The important weight synthesized depends on the sensitivity parameter, alpha, whose value is set to 0.5, and the variation interval is zero to one. The alpha parameter is increased by 50% of the sensitivity parameter, which is 0.75, and also decreased by 50% of the same parameter, which is worth 0.25 nonlinear value change in priority vector for sub-criteria in the alternative, the influence of sub-criteria selected, following linear changes in alpha parameter control.

For sensitivity analysis concerning the sub-criteria 'Minimum number of raw materials with Not Good label in incoming status', the value 0.5 for alpha produces a synthesized priority vector as in Figure 4, in the bar representation. This is shown in Figure 4. The correspondent priority vector for the parameter alpha value increases to 0.75 and decreases to 0.25 can be seen in Figure 5 and Figure 6.

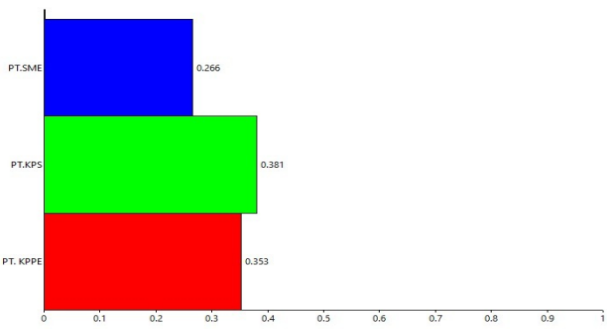

Figure 4. Sensitivity analysis to sub-criteria 'Minimum number of raw materials with Not Good label in incoming status'.

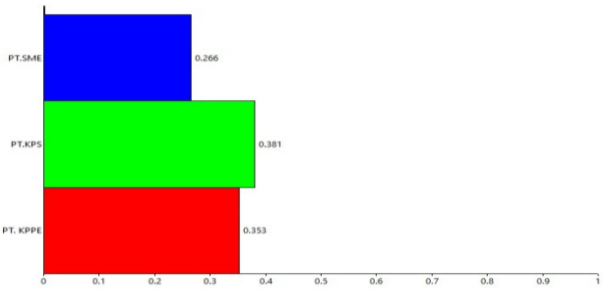

Figure 5. Sensitivity analysis to sub-criteria 'Minimum number of raw materials with Not Good label in incoming status' with a 50% decrease of the importance'.

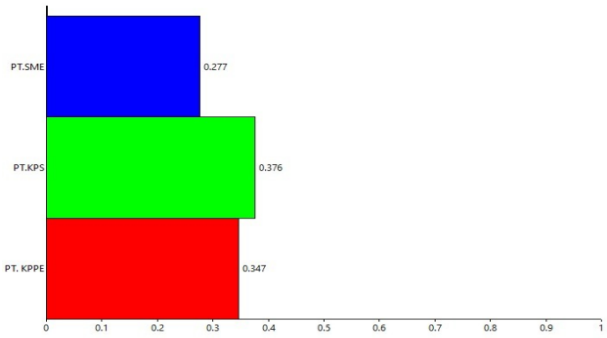

Figure 6. Sensitivity analysis to sub-criteria 'Minimum number of raw materials with Not Good label in incoming status' with a 50% importance increase'.

Table 11. Sensitivity to 'Minimum number of raw materials with Not Good label in incoming status'.

Alternative	Alpha 0.25	Alpha 0.5	Alpha 0.75
PT. KPPE	0.355 (0.567%)	0.353	0.347 (-1.67%)
PT. KPS	0.382 (0.263%)	0.381	0.376 (-1.312%)
PT. SME	0.263 (-1.128%)	0.266	0.277 (3.971%)

The graph above shows the sensitivity of sub-criteria 'Minimum number of raw materials with Not Good label in incoming status.' For more details, the Sensitivity of the sub-criteria is outlined in Table 11.

As can be seen in the table above, the alternate list is on the second column, whose alphas are 0.25, 0.5, and 0.75. Parentheses associated with a decrease or increase in alpha parameters of 50% indicate the rate of priority vector change. If the priority is increased by 50%, the percentage of alternatives will be affected by 0.989%. If the priority is lowered by 50%, the alternative will be affected by 0.3%. The weight value on the sub-criteria' Minimum number of raw materials with Not Good label in incoming status' has been changed, and it appears that the highest priority is PT KPS, then is PT KPPE, and finally is PT SME. It can be seen at the least change on each value. So, there are no significant changes even against the weight of the sub-criteria value' inimum number of raw materials with Not Good label in incoming status' addition or subtraction.

Conclusion

Based on the results and discussions, it can be concluded that on the calculation of ANP, the highest criterion to influence the selection of suppliers is the quality because the quality of products from suppliers will also clearly affect the quality of products produced. The price criterion follows it because if companies require sound quality but the price offered is too expensive, the companies' finance will be affected. The third rank is customer care because suppliers must communicate and serve customers by providing the correct information to avoid problems during product transactions from suppliers. The packaging criterion of raw materials is at the last rank because companies rarely receive damaged product packaging during the history of product processing. The companies have received damaged packaging several times, but they were not damaged too much and could still be used.

References

1. Chai, J., and Ngai, E. W., Decision-Making Techniques in Supplier Selection: Recent Accomplishments and What Lies Ahead, *Expert Systems with Applications*, 140, 2020, 112903.
2. Karpak, B. Reflections: Mathematical Principles of Decision Making, *International Journal of Analytical Hierarchy Process*, 9(3), 2017, pp.17-25.
3. Alikhani, R., Torabi, S. A., and Altay, N., Strategic Supplier Selection under Sustainability and Risk Criteria, *International Journal of Production Economics*, 208, 2019, pp. 69-82.
4. Hendiani, S., Liao, H., Ren, R., and Lev, B., A Likelihood-based Multi-criteria Sustainable Supplier Selection Approach with Complex Preference Information, *Information Sciences*, 536, 2020, pp.135-155.
5. Ishizaka, A., Analytic Hierarchy Process and Its Extensions, In *New Perspectives in Multiple Criteria Decision Making*, Springer, Cham, 2019, pp. 81-93.
6. Jain, N., Singh, A. R., and Upadhyay, R. K., Sustainable Supplier Selection under Attractive Criteria through FIS and Integrated Fuzzy MCDM Techniques, *International Journal of Sustainable Engineering*, 13(6), 2020, pp. 441-462.
7. Navarro, N., Valverde, P. D. F., Quesada, H. J., and Madrigal-Sánchez, J., *A Supplier Selection Model for the Wood Fiber Supply*,2020.
8. Song, W., Xu, Z., and Liu, H. C., Developing Sustainable Supplier Selection Criteria for Solar Air-Conditioner Manufacturer: An Integrated Approach. *Renewable and Sustainable Energy Reviews,* 79, 2017, pp. 1461-1471.
9. Aghasafari, H., Karbasi, A., Mohammadi, H., and Calisti, R., Determination of the Best Strategies for Development of Organic Farming: A SWOT–Fuzzy Analytic Network Process Approach, *Journal of Cleaner Production*, 277, 2020, 124039.
10. Giannakis, M., Dubey, R., Vlachos, I., and Ju, Y., Supplier Sustainability Performance Evaluation using the Analytic Network Process. *Journal of Cleaner Production*, 247, 2020, 119439.
11. Uzunlar, F. B., Güler, Ö., and Kalenderli, Ö., Wind Turbine Selection Method By Using Analytical Network Process Associated with Cost Benefit Analysis. *Environmental Engineering and Management Journal*, 19(5), 2020, pp.873-883.

12. Lancharoen, S., Suksawang, P., and Naenna, T., Readiness Assessment of Information Integration in a Hospital using an Analytic Network Process Method for Decision-making in a Healthcare Network, *International Journal of Engineering Business Management*, 12, 2020, 1847979019899318.
13. Singha, S., and Pasupuleti, S., Delineation of Groundwater Prospect Zones in Arang Block, Raipur District, Chhattisgarh, Central India, Using Analytical Network Process, *Journal of the Geological Society of India*, 95(6), 2020, 609-615.
14. Arvidsson, A. P., and Melander, L., The Multiple Levels of Trust when Selecting Suppliers–Insights from an Automobile Manufacturer. *Industrial Marketing Management*, *87*, 2020, pp. 138-149.
15. Sagnak, M., Selecting the Most Appropriate Supplier in the Green Environment: A Hybrid Multi-Criteria Decision-Making Application. *In Handbook of Research on Industrial Applications for Improved Supply Chain Performance*. IGI Global, 2020, pp. 101-124.
16. Raut, R. D., Gardas, B. B., Narkhede, B. E., and Zhang, L. L., Supplier Selection and Performance Evaluation for Formulating Supplier Selection Strategy by MCDM-based Approach. *International Journal of Business Excellence*, 20(4), 2020, pp. 500-520.
17. Kumar, S., Kumar, S., and Barman, A. G., Supplier Selection using Fuzzy TOPSIS Multi Criteria Model for a Small Scale Steel Manufacturing unit. *Procedia computer Science*, *133*, 2018, 905-912.
18. Mu, E., Cooper, O., and Peasley, M., Best Practices in Analytic Network Process Studies. *Expert Systems with Applications*, 159, 2020, 113536.
19. Hadian, H., Chahardoli, S., Golmohammadi, A. M., and Mostafaeipour, A., A Practical Framework for Supplier Selection Decisions with an Application to the Automotive Sector. *International Journal of Production Research*, 58(10), 2020, 2997-3014.
20. Choi, H., Park, K. S., and Kim, J., An Analytic Network Process Model to Select Supplier of Energy Production Facility of a Synthetic Fiber Production Company, *The Journal of the Korea Contents Association*, 18(12), 2018, 291-298.
21. Maestrini, V., Luzzini, D., Maccarrone, P., Caniato, F., Supply Chain Performance Measurement Systems: A Systematic Review and Research Agenda, *International Journal of Production Economic*, 183 Part A, 2017, pp. 299-315.
22. Han, Y., Geng, Z., Zhu, Q., Wang, Z., and Cui, Y., Energy Consumption Analysis and Evaluation of Petrochemical Industries using an Improved Fuzzy Analytic Hierarchy Process Approach, *Journal of Intelligent and Fuzzy Systems*, 32(6), 2017, pp. 4183-4195.
23. Taherdoost, H., and Brard, A., Analyzing the Process of Supplier Selection Criteria and Methods, *Procedia Manufacturing*, 32, 2019, pp. 1024-1034.
24. Rashidi, K., Noorizadeh, A., Kannan, D., and Cullinane, K., Applying the Triple Bottom Line in Sustainable Supplier Selection: A Meta-Review of the State-of-the-art, *Journal of Cleaner Production*, 2020, 122001.
25. Chen, K. S., Chung, L., and Chang, T. C., Developing a Quality-based Supplier Selection Model from the Buying Company Perspective, *Quality Technology and Quantitative Management*, 18(3), 2020, pp. 267-284.
26. Tusnial, A., Sharma, S. K., Dhingra, P., and Routroy, S., Supplier Selection using Hybrid Multi-criteria Decision-making Methods. *International Journal of Productivity and Performance Management*, 70(6), 2020, pp.1393-1418.
27. Saaty, T. L., and De Paola, P., Rethinking Design and Urban Planning for the Cities of the Future, *Buildings*, 7(3), 2017, pp. 1–22.
28. Goepel, K. D., Comparison of Judgment Scales of the Analytical Hierarchy Process - A New Approach. *International Journal of InformationTechnology and Decision Making*, 18(2), 2019,pp. 445–463
29. Asadabadi, M. R., Chang, E., and Saberi, M., Are MCDM Methods Useful? A Critical Review of Analytic Hierarchy Process (AHP) and Analytic Network Process (ANP), *Cogent Engineering*, 6(1), 2019, 1623153.
30. Ririh, K. R., Ningtyas, D. R., and Utami, D. A ., Strategy for Reducing Material Waste of Ready-Mix Concrete Production through Analytical Hierarchy Process (A Case Study). *Proceedings of the 5th NA International Conference on Industrial Engineering and Operations Management*, 2020, 3288-3296.