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Selecting Supplier with Analytical Hierarchy Process (AHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS): A Case Study at PT. Perta Daya Gas Semarang

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ABSTRACT

Supplier is an important part of the supply chain. The appropriate supplier would maintain the company's competitive advantage, and multi-criteria decision-making is applied in selecting suppliers. PT. Perta Daya Gas is a company that provides infrastructure and storage services for compressed natural gas. Machines are needed for operational activities that need components; one is the exhaust manifold. There are some considerations in selecting an exhaust manifold supplier, such as quality, delivery, price, and company conditions. Selecting suppliers use the Analytical Hierarchy Process (AHP) method for weighting, then continue to rank suppliers using the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method. Based on the AHP method, quality has the highest weight of 54.9%, and the highest weight on sub-criteria is the specification, 38.2%. Based on the TOPSIS method, PT. A has the highest preference value of 0.712. It shows that PT A is the best supplier, which could be prioritized in fulfilling the supply exhaust manifold in PT Perta Daya Gas.

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1. INTRODUCTION

The globalization supply chain allows the company to acquire various materials from the world market through outsourcing. Outsourcing is a potential strategy in achieving the success of the supply chain. Outsourcing is also seen as a strategy for cost reduction and increased company competitiveness [1]. Outsourcing makes the company focus on its core business to face the competition in the market. The company enhances the search for suppliers to perform the work previously undertaken in the company [2].

In supply chain management, coordination between manufacturer and supplier is an important relationship. If the supplier becomes a part of a well-coordinated supply chain, it will impact the competitiveness of all supply chain parts [3]. The selection of suitable suppliers makes a strategic difference in the ability of the organization to perform continuous improvement to meet customer satisfaction [4]. Over the years, the traditional approach to supplier selection is merely considering the price. Then the company began to realize that the selection of suppliers with consideration of one criterion was not efficient anymore. They began to conduct elections with multi-criteria

considerations [4]. The company can strengthen its strategic position through supplier selection. The decision on the supplier selection is complex. A lot of qualitative and quantitative performance indicators such as quality, price, flexibility, and timeliness should be considered in the selection of suppliers. Supplier selection is a problem of Multi-Criteria Decision Making (MCDM) which must be resolved by the approach in MCDM [5].

In the implementation of its core business as the infrastructure and storage provider of the Compressed Natural Gas (CNG), PT Perta Daya Gas requires suppliers to support the company's business. Suppliers of goods and services that cooperate with PT Perta Daya Gas are derived from various business sectors. The components of the machine are one of the goods that are outsourced. Based on the purchasing data component for the corrective maintenance in 2019, exhaust manifold consumes 25% of the cost from the total cost for the maintenance corrective components purchasing in the year 2019. Because of the amount of cost, it needs proper supplier selection analysis for exhaust manifold purchasing. If the cost for this exhaust manifold can be analyzed appropriately, there is a potential cost reduction in the company considering the use of costs for purchasing exhaust manifold is highest in the purchasing of maintenance corrective components in 2019. Exhaust manifold is supplied from five suppliers where each supplier has different characteristics. Therefore, research is needed to determine which supplier is the best in supplying exhaust manifold to PT Perta Daya Gas Semarang. The selection of the right supplier can lead to a large amount of savings on the company cost [6].

The research uses AHP and TOPSIS methods. The AHP method is an effective decision-making framework for resolving complex issues by simplifying problems and putting them together in a hierarchy. AHP method is a systematic method and does not take a long time and can show the priority weights of selected criteria and suppliers. [7]. The three main elements in AHP are construction hierarchy, priority analysis, and consistency verification. First, decision-makers need to break down the complex decision-making criteria into the components that will be formed in a multilevel hierarchy. Secondly, decision-makers compare each element at the same level to a pair of comparisons based on decision-making assessments. Due to the comparison of the subjective assessment, there is a possibility of inconsistency. To ensure that the given assessment is consistent, the third element, consistency verification, is one of the significant advantages of AHP for measuring the consistency ratio. If the consistency ratio exceeds the specified limit, the decision-maker should review and correct the comparison of pairs that have been performed. If the comparison pair is consistently stated, the assessment can be synthesized to rank for each criterion. [8].

The TOPSIS method is used to measure the relative performance of alternative decisions in the form of mathematically which can be considered so that it can determine the best supplier through the criteria specified [9]. The method was first introduced by Hwang and Yoon in 1981 and was developed in 1987 and 1992. TOPSIS uses the principle that selected alternatives have the closest distance from an ideal positive solution and are the farthest of the ideal negative solution from a geometric standpoint by using a euclidean distance to determine the relative proximity of an alternative with optimal solutions. [10]. The advantage of this method is [11].

1. Simple, rational, comprehensive concept.
2. The logic is intuitive and clear which shows a rational human choice.
3. Easy to calculate and efficiently in calculations.
4. The value that indicates the best and worst solution that is measured against alternatives expressed in simple mathematical form.

In general, the process in the TOPSIS algorithm starts from the formation of a decision matrix that shows the satisfaction value of each criterion against each alternative. Then the matrix is normalized and the value is multiplied by the criteria weight. Then the

ideal positive solution and the ideal negative solution are calculated, the distance for each alternative to the ideal solution is calculated. Then alternative solutions were ranked based on their proximity to the ideal solution. The TOPSIS technique is beneficial for decision-makers in constructing issues to solve, making analysis, comparisons, and ratings for alternatives [11].

The use of both of these methods in the selection of suppliers changes the subjective and objective opinions of experts into quantitative form with the AHP method, then the rating of supplier is calculated using the TOPSIS method [12]. AHP method is used to weighted the criteria and sub-criteria of selecting the best exhaust manifold supplier. This AHP method is used because it helps to solve complex problems with hierarchy construction and considering the various factors that affect it. In addition, in AHP there is also a calculation of the weighted consistency. However, in AHP method does not count the distance between the ideal solution to the supplier alternatives. The TOPSIS method is used for the best selection of supplier exhaust manifold alternatives. This selection is based on the relative proximity of alternatives to the ideal positive and negative solutions. In the TOPSIS method, there is no consistency testing to test the judgment of respondents, but the excess of this method is being able to make practical decisions by taking into account the alternative distance to the ideal solution. Based on the weaknesses and advantages of both methods, it is a combination of AHP and TOPSIS methods, in which the AHP method is applied to the weighted criteria and subcriteria and TOPSIS to conduct supplier ratings based on input from AHP criteria. Both methods are combined to meet the best decision.

2. METHODOLOGY

Collecting Data

Data that is collected to select the best supplier are company overview, exhaust manifold supplier data in 2019, selection criteria for suppliers in PT Perta Daya Gas in 2019, organs of the company related to from procurement, inspection, until user, that is staff of purchasing, planning, inventory, and user. The techniques for data collection are literature study and field study. The study of literature is conducted by reading literature, books, journals, articles, scientific papers related to this research, such as Standard Operating Procedure (SOP) to obtain secondary data, develop a framework of theory and determine the direction, objectives, and concept of research to appropriate to the problems.

Field studies are conducted by interviews, questionnaires, and observations. The interview was conducted with purchasing staff of supplier exhaust manifold which supply company and criteria used for the selection of supplier exhaust manifold in the company. Questionnaires are used for the weighted criteria, sub-criteria, and suppliers. Respondents involved in the filling of this questionnaire are staff of purchasing, planning, inventory, and user with the consideration that the parties are related to the procurement process, examination, until the use of exhaust manifold in the company. There are two questionnaires in this study, the first questionnaire for weighting criteria and sub-criteria and a second questionnaire for weighting suppliers. Observation is conducted by direct observation to the field to know the condition and get an overview of the procurement process in the company.

Analyzing Data

Analytical Hierarchy Process (AHP)

Weighted criteria and Subcriteria using the AHP method with steps:

a. Distributing questionnaire
   The filling of questionnaires I and II uses a Likert 1-9 scale. Here are the Likert scales used

Table 1 Likert Scale

Scale	Description
1	Both elements are equally important, both elements have an equally large influence
3	The one element is slightly more important than the other elements
5	The one element is strongly more important than the other elements
7	The one element is very strongly more important than the other elements
9	The one element is absolutely more important than the other elements
2,4, 8,6	Values between two values of contiguous considerations, this value is given when there are two compromises between two options

Source: Saaty dan Vargas, 2012

b. Constructing a Paired Comparison Matrix
From questioner, there are paired comparison values for criteria, sub-criteria, and supplier. In this study involved several employees so that the comparison results in pairs should be calculated with a geometric mean.

c. Normalizing Paired Comparison Matrix

$$B_{ij} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}}$$

B_{ij} = normalization element matrix row i coloumn j
a_{ij} = A element matrix

d. Weighting element

$$b_i = \frac{1}{m}\left(\sum_{j=1}^{m} b_{ij}\right)$$

m = the number of column
b_i = weight row i
b_{ij} = total sum of row i

e. Consistency test

$$\lambda_{maks} = \frac{\sum_{i=1}^{n} \lambda}{n}$$

λ = *eigen value*
λ_{max} = *eigen value* maximum
n = the number of considering criteria

$$CI = \frac{\lambda_{maks} - n}{n-1}$$

CI = consistency index
n = the number of considering criteria

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

CR = consistency ratio
RCI = Random Consistency Index

Table 2 Random Consistency Index

n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RCI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

Source: Saaty dan Vargas 2012

Consistency is showed by the consistency ratio value. Consistent questioner has consistency ratio value not higher than 10% or 0,100.

***Technique for Order Preference by Similarity to Ideal Solution* (TOPSIS)**

Here are the steps in the TOPSIS method.

1. Constructing normalization matrix
This matrix derived from AHP calculation which is normalized by using this formula.

$$n_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}}$$

n_{ij} = normalization matrix row i coloumn j
x_{ij} = matix element row i coloumn j
v_{ij} = elemen matriks normalisasi terbobot baris i kolom j

2. Constructing Weighted Normalization Matrix

$v_{ij} = w_j . n_{ij}$

w_j = *global weight* coloumn j (criteria)
n_{ij} = normalization matrix row i coloumn j

3. Determine Positive Ideal Solution and Negative Ideal Solution.

$A^+ = (v_1^+, v_2^+, \dots, v_n^+) = (\max v_{ij} | j \epsilon I)$
$A^- = (v_1^-, v_2^-, \dots, v_n^-) = (\min v_{ij} | j \epsilon I)$

A^+ = Positive ideal solution
A- = Negative ideal solution

4. Determine Distance Between Alternative and Ideal Solution

$d_i^+ = \sqrt{\sum_{j=1}^{m} (v_{ij} - v_j^+)^2}$

$d_i^- = \sqrt{\sum_{j=1}^{m} (v_{ij} - v_j^-)^2}$

d_i^+ = distance between alternative and positive ideal solution
d_i^- = distance between alternative and positive ideal solution
d_j^- = negative ideal solution j coloumn
d_j^+ = positive ideal solution j coloumn

5. Ranking Alternative

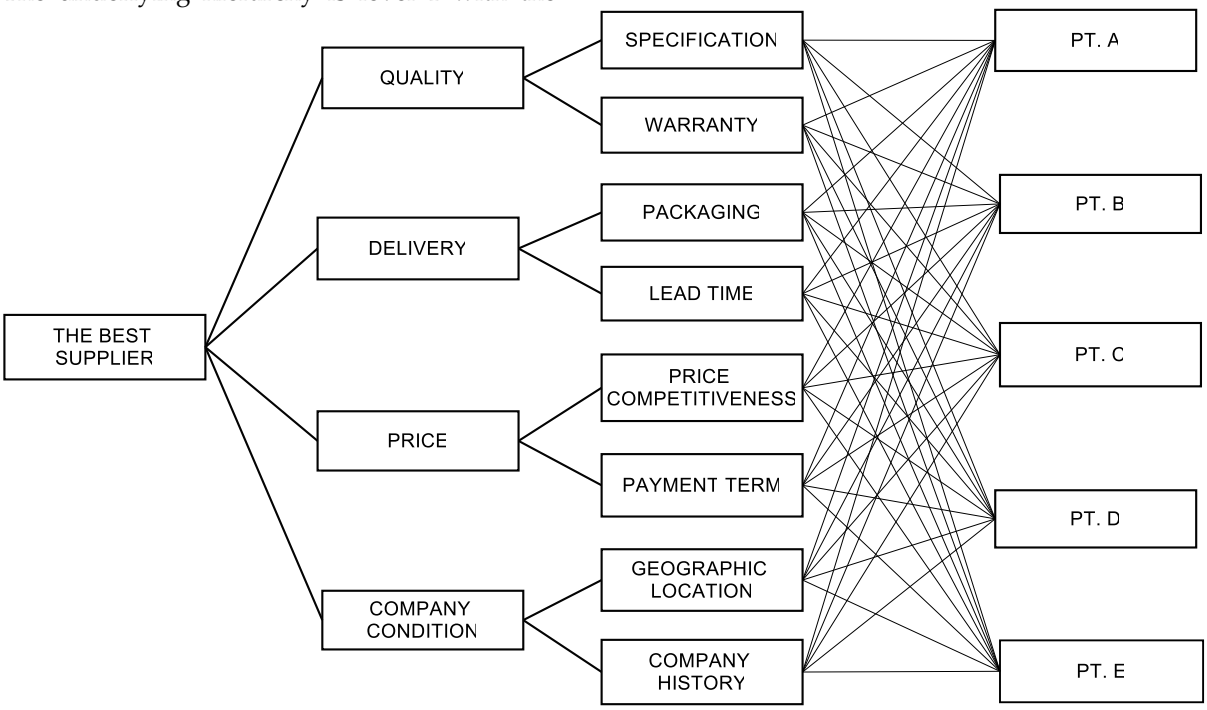
$R_i = \frac{d_i^-}{d_i^- - d_i^+}$

R_i = rating of alternative

3. RESULT AND DISCUSSION

Constructing Decision Hierarchy

The decision hierarchy for supplier selection consists of level 0 which is the goal. The underlying hierarchy is level 1 with the main criteria, then the second-level hierarchy is the assessment subcriterion resulting from the data processing of the questionnaire, and the third level hierarchy is the supplier alternative.



Picture 1 Decision Hierarchy of Selecting Supplier
Source: Researcher Analysis

Weighting Main Criteria

From the result of the questioner which is filled by employees, the geometric mean is searched for every element of the matrix so that the result obtained as shown in table 3.

Table 3 Geometric Mean of Main Criteria Paired Comparison Matrix

Main Criteria	Quality	Delivery	Price	Company History
Quality	1.000	2.813	3.771	2.697
Delivery	0.297	1.000	1.110	2.964
Price	0.265	1.164	1.000	1.587
Company Condition	0.371	0.445	0.548	1.000
Column Sum	1.933	5.422	6.429	8.249

Source: Researcher Analysis

Table 4 Normalization Matrix of of Main Criteria Paired Comparison Matrix

Main Criteria	Quality	Delivery	Price	Company History
Quality	0.517	0.519	0.587	0.327
Delivery	0.154	0.184	0.173	0.359
Price	0.137	0.215	0.156	0.192
Company Condition	0.192	0.082	0.085	0.121

Source: Researcher Analysis

Table 5 Calculating λ of Main Criteria Paired Comparison Matrix

Main Criteria	Quality	Delivery	Price	Company History	*Global Weight*	λ
Quality	0.517	0.519	0.587	0.327	0.487	4.273
Delivery	0.154	0.184	0.173	0.359	0.218	4.194
Price	0.137	0.215	0.156	0.192	0.175	4.275
Company Condition	0.192	0.082	0.085	0.121	0.120	4.109

Source: Researcher Analysis

λ_{max} = 4.213
CI = 0.071
CR = 0.079 (7.9%)

Because the CR value is 0.079 which is less than 0.100 so that the result of the first questionnaire is consistent and is used in the next step.

Weighting Sub-criteria

The weight to be counted is local weight and global weight. The local weight is derived from the average number of elements on each row, while the global weight is derived from the multiplication between the local weights and the weight of the criteria in which the sub-criteria reside. The Global weight of 8 subcriteria if aggregated is worth 1. In weighting sub-criteria, it uses the same steps in the weighting criteria. After the calculation, obtained the weight of each subcriterion is as shown in table 5.

Table 5 Sub-criteria Weight

No	Criteria	Criteria Weight	Sub-criteria	Local Weight of Sub-criteria	Global Weight of Sub-criteria
1.	Quality	0.549	Specification	0.784	0.382
			Warranty	0.216	0.105
2.	Delivery	0.202	Packaging	0.311	0.068
			Lead Time	0.689	0.150
3.	Price	0.120	Price Competitiveness	0.726	0.127
			Payment Term	0.274	0.048
4.	Company Condition	0.130	Geographical Location	0.418	0.050
			Company History	0.582	0.070

Source: Researcher Analysis

Weighting Alternative Supplier

Using the second questionnaire data, the best supplier can be determined. Weighting suppliers use the same steps in weighting criteria. After the calculation, obtained the weight of each supplier against the Subcriteria is as shown in table 6.

Table 6 Weighting Altenative to Sub-criteria

Alternative *Supplier*	Speci-fication	Warranty	Pack-aging	*Lead Time*	Price Competiti-veness	Payment term	Geograph-ical Location	Company History
PT. A	0.113	0.020	0.014	0.027	0.058	0.010	0.015	0.015
PT. B	0.054	0.020	0.012	0.043	0.013	0.010	0.011	0.011
PT. C	0.038	0.018	0.012	0.034	0.006	0.005	0.008	0.010
PT. D	0.051	0.017	0.012	0.035	0.012	0.009	0.008	0.009
PT. E	0.126	0.029	0.017	0.011	0.039	0.014	0.009	0.024
CR	1%	3%	0%	2%	8%	2%	2%	2%

Source: Researcher Analysis

The CR value obtained for each comparison pair of supplier weighted to sub-criteria is less than 10% so that the questionnaire result is consistent and used for TOPSIS input.

Ranking Supplier using TOPSIS

In this TOPSIS calculation, input data use the result of weighting supplier to subcriteria that have been calculated the consistency in the AHP method. Input data using data in table 6. Then it normalized and the result is shown in table 7 and table 8.

Table 7 Normalization Matrix in TOPSIS Method

Global Weight	0.382	0.105	0.068	0.150	0.127	0.048	0.050	0.070
Alternative *Supplier*	Speci-fication	Warranty	Pack-aging	*Lead Time*	Price Competiti-veness	Payment term	Geograph-ical Location	Company History
PT. A	0.597	0.425	0.471	0.379	0.806	0.453	0.639	0.437
PT. B	0.287	0.423	0.382	0.605	0.179	0.457	0.458	0.331
PT. C	0.202	0.383	0.406	0.477	0.077	0.211	0.338	0.311
PT. D	0.268	0.347	0.398	0.489	0.159	0.410	0.359	0.283
PT. E	0.670	0.611	0.556	0.153	0.535	0.611	0.373	0.723

Source: Researcher Analysis

Table 8 Weighted Normalization Matrix in TOPSIS Method

Global Weight	0.382	0.105	0.068	0.150	0.127	0.048	0.050	0.070
Alternative *Supplier*	Speci-fication	Warranty	Pack-aging	*Lead Time*	Price Competiti-veness	Payment term	Geograph-ical Location	Company History
PT. A	0.228	0.045	0.032	0.057	0.102	0.022	0.032	0.031
PT. B	0.110	0.045	0.026	0.091	0.023	0.022	0.023	0.023
PT. C	0.077	0.040	0.027	0.072	0.010	0.010	0.017	0.022

PT. D	0.102	0.037	0.027	0.073	0.020	0.020	0.018	0.020
PT. E	0.256	0.064	0.038	0.023	0.068	0.029	0.019	0.051

Source: Researcher Analysis

By using the weighted normalization matrix above, positive ideal solution and negative ideal negative solution are calculated. The calculation of the ideal positive solution by finding the maximum element value on each sub-criteria, while calculation the negative ideal solution is done by finding the minimum value of element on each sub-criteria. Here are the results of counting positive ideal solutions and negative ideal solutions. Where C1 is the specification, C2 is the warranty, C3 is packing, C4 is the lead time, C5 is price competitiveness, C6 is the payment requirement, C7 is the geographical location, and C8 is the company history.

Table 9 Positive Ideal Solution and Negative Ideal Negative Solution

A +	C1 MAX	C2 MAX	C3 MAX	C4 MAX	C5 MAX	C6 MAX	C7 MAX	C8 MAX
	0.253	0.064	0.041	0.091	0.102	0.029	0.032	0.050
A -	C1 MIN	C2 MIN	C3 MIN	C4 MIN	C5 MIN	C6 MIN	C7 MIN	C8 MIN
	0.077	0.037	0.026	0.023	0.010	0.010	0.017	0.020

Source: Researcher Analysis

The next step is calculating the distance between alternative to negative ideal solution and positive ideal solution.

Table 10 Distance Between Alternative to Negative Ideal Solution and Positive Ideal Solution

d_i^+		d_i^-	
PT. A	0.050	PT. A	0.185
PT. B	0.168	PT. B	0.078
PT. C	0.205	PT. C	0.049
PT. D	0.178	PT. D	0.058
PT. E	0.077	PT. E	0.191

Source: Researcher Analysis

The principle of the TOPSIS method is to choose alternatives that have the closest distance to the ideal solution positive (di+) and have the farthest distance with the ideal negative solution (di-). Table 11 below shows the rating of each supplier and its range based on TOPSIS calculation.

Table 11 Supplier Ranking Based on TOPSIS Method

Alternative *Supplier*	Rating	Ranking
PT. A	0.787	I
PT. B	0.316	III
PT. C	0.192	V
PT. D	0.246	IV
PT. E	0.712	II

Source: Researcher Analysis

4. CONCLUSION

Based on the analysis that has been done in the previous calculation, it can be concluded that based on the calculations using Analytical Hierarchy Process (AHP), in the selection of supplier exhaust manifold there are criteria that weight each considered the criteria quality (54.9%) which consist of two sub-criteria that are specification (38.2%) and warranty (10.5%), criteria delivery (20.2%) which consist of two sub-criteria that are packaging (6.8%) and lead time (15%), criteria price (12.0%) which consist of two sub-criteria that are price competitiveness (12.7%) and payment terms (4.8%), and criteria company condition (13.0%) consisting of two sub-criteria that are geographical location (5%) and company history (7%).

Based on the weighted criteria and subcriteria that have been calculated, the supplier rating is calculated using the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method. The first rank is PT. A with 0.787 in rating, the second rank of PT. E with 0.712 in rating, the third rank of PT. B with 0.316 in rating, the fourth rank of PT. D with 0.246 in rank, and the last rank of PT. C with 0.192 in rank. PT. Perta Daya Gas could consider prioritizing PT. A according to the AHP and TOPSIS method is the best supplier as the main supplier of exhaust manifold to support the optimal business activities in PT. Perta Daya Gas

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