

# Selection of Tugboat Gearboxes Supplier Using the Analytical Hierarchy Process Method

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P A P E R I N F O	A B S T R A C T
<p><b>Chronicle:</b> Received: 03 June 2018 Revised: 18 September 2018 Accepted: 09 November 2018</p>	<p>Some company strategies in managing business that can be implemented are Supply Chain Management (SCM). SCM works to ensure the availability of the material obtained from the supplier. With the increasingly advanced information technology in line with the progress in hardware and software technologies, the computing methods are also growing. One of the most important computing methods in its development is the Decision Support System (DSS). Every company is required to move quickly in decision-making or action, similarly, in the selection of suppliers. With reference to the Hierarchy Analytical Process (AHP) method, this research aims to make decisions in the selection of suppliers objectively based on the various criteria set. This is made so that the goods supply process can be run according to the needs of the company as one of the utilization and availability of Tugboat.</p>
<p><b>Keywords:</b> SCM. Supplier. DSS. AHP.</p>	

## 1. Introduction

The company as a system to carry out production activities in the form of products/services requires raw materials and energy which of course are imported from suppliers. If the supplier is unable to provide feedback and is responsible for fulfilling the request, it will cause problems including the idling time and waiting periods. Given the many criteria to consider supplier management, it is necessary to assess the performance of the supplier. A method used in measuring supplier performance is an analytical hierarchical process. Additionally, supplier selection is aimed at finding suppliers who are able to provide buyers with precise quality products or services at the right prices, at the right amount, and at the right time [6].

One of the departments or sub-fields of work that plays an important role in achieving corporate goals is supply chain management. Supply Chain Management (SCM) is a corporate network that works together to create and deliver products to the end users. According to [3], SCM is a concept of trade process flow management that connects the manufacturers, suppliers, and users directly. Based on both definitions above it can be concluded that SCM is a chain of procurement of goods to customers in order to ensure the availability of material and minimize costs.

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PT. GTEI is a rental of Tugboat Coal Company in the Republic of Indonesia. Tugboat has many important components to support delivery, one of which is gearboxes. If gearboxes are breakdown, tugboats cannot sailing because the gearbox procurement process takes a long time, 2 month until 3 months. Because many suppliers cannot meet the need for quick gearboxes, researchers choose suppliers to get the tugboat gear box using the analytical hierarchy process method.

## 2. Research Methods

Testing of measuring instruments

- Validity test:

Validity shows the extent to which a measuring instrument measures what it wants to measure [2]. In this study, the test is done using the Cochran Q Test. The steps of the Cochran Q Test are:

- Calculates the number of respondents from the questionnaire data that agrees that the considered criteria can be used as a decision-making criteria.
- Configure a hypothesis :
  - H0: All tested attributes have the same proportion of "yes" answers.
  - H1: Not all tested attributes have the same proportion of "yes" answers.
- Calculate  $Q_{hit}$  value with formula:

$$Q_{hit} = \frac{(k - 1)[k \sum_j^k C_j^2 - (\sum_j^k C_j)^2]}{k \sum_i^n R_i - \sum_i^n R_i^2}, \quad (1)$$

where, k = Number of criteria,  $C_j$  = The number of respondents who chose "yes" on the criteria to-j,  $R_i$  = The number of criteria approved by the respondent to-i.

- Decide Q table with  $\alpha = 0.05$  and degree of freedom (dk) = k-1, then obtaine Q value table (0,05; dk) that comes from Chi Square table.
- Comparing the value of Q table with Q calculate where:
  - $Q_{hit} > Q_{tab}$  = reject H0.
  - $Q_{hit} < Q_{tab}$  = accept H0.
- Summarize the obtained results:
  - If reject H0 means the perception of the "yes" answer is still different on all attributes which means there is a difference of opinion on the attribute. The next thing that is done is to eliminate attributes that have the least proportion of "yes" answers.
  - If accept H0 means the proportion of "yes" answer for each attribute is considered equal and meaning all respondents agree on all criteria as considered factors.
- Reability test.

Reability comes from the word reability which means the extent to which the measurement results can be trusted [8]. According to Nur in [8], the measurable results are measurable if in some measurements of the same subject group, the results of relative measurements are equally as long as the aspects measured in the subject do not change. The calculation steps are as follows:

- Determine the Hypothesis.
  - H0 = there is no difference between test results I and testing II.
  - H1 = there is difference between test results I and testing II.

- Calculate  $\chi^2$  value:

$$\chi^2 = \frac{n[(AD - BC) - n/2]^2}{(A + B)(C + D)(A + C)B_D} \quad (2)$$

- Determine the criticism value of  $\chi^2$  with significance level of 5% and degree of freedom ( $dk$ ) = 1. Then the critique value  $r$  (0.05;  $dk$ ) is obtained from the critique number table  $\chi^2$  value.
- Conclusion:

If the obtained value of  $\chi^2$  is below the critical value,  $H_0$  is accepted and concluded that there is no difference between measurement I and measurement II (reliable); whereas if the obtained value of  $\chi^2$  exceeds the critic value,  $H_0$  is rejected which means there is a significant difference between measurement I and II measurement so the data obtained is not reliable.

### Analytical hierarchy process method

This method is used to synthesize the comparison of decision-making that is paired at each level of decision hierarchy, how to determine the relative priority of each element of the decision where the weight is to indicate the preferential choice or decision element [4]. According to [7] many results have been solved by the AHP method from various fields such as planning, choosing the best alternative, and resource allocation to resolving the conflict for optimization.

#### Eigenvalue and eigenvector

Eigenvector is a vector that when is multiplied by a matrix, the result is the vector itself multiplied by a scalar number or parameter which is none other than eigenvalue [2]. Eigenvectors are usually referred to as characteristic vectors of a square matrix while Eigenvalue is the characteristic root of the matrix. The form of the equation is:

$$A \cdot w = \lambda \cdot w, \quad (3)$$

where  $A$ = Square matrix,  $W$ = eigenvector, and  $\lambda$  = eigenvalue.

## 3. Study and Analysis

### Data accumulation

- Criteria of data:

Criteria of data refers to the research of [1], consisting of 23 criteria: Quality, delivery, work experience, guarantee and claims, production facilities and capacity, price, and technical capabilities; financial condition, compliance records, communications system, reputation and position in the industry, desire to collaborate, management and organization, operational surveillance, service improvement, and attitude; impression, packaging capabilities, contact record with worker, location, number of branches, training aid, and defense regulations.

- Supplier data:

Supplier data used in this research is based on purchase order in 2018 to spare parts of Gearbox is:

- PT. ABC.
- PT. DEF.
- PT. GHI.
- PT. JKL.
- PT. MNO.

In this study, 4 questionnaires were distributed to 5 respondents. Questionnaires are in the form of

- Questionnaire I: Distribution of my questionnaire to determine whether these criteria are needed or required in the supplier's assessment.
- Questionnaire II: Questionnaire II is basically the same as my questionnaire where questionnaire II is to carry out a reliability test with a test method (test-retest).
- Questionnaire III: Questionnaire III has been conducted to collect data on the five priority of respondents about the comparison between the criteria and among the sub criteria by providing importance assessment for criteria and sub criteria using Saaty scale.
- Questionnaire IV: Questionnaire IV contains the assessment of each supplier of materials on each sub criteria.

5 respondents in this study are:

- Respondent 1: Material strategic procurement.
- Respondent 2: Administration and development.
- Respondent 3: Staff purchasing.
- Respondent 4: Technic.
- Respondent 5: Crew engine.

Data processing

- Validity test:

The validity test uses the questionnaire II which is then assisted with the help desk with the decision.

From the data obtained in Table 1, it is known:

$$\sum_{i=1}^{23} C_i = 104; \sum_{i=1}^{23} C_i^2 = 484 ;$$

$$\sum_{j=1}^5 R_j = 104; \sum_{j=1}^5 R_j^2 = 2182 .$$

Therefore, the Q count can be obtained by the equation.

$$Q \text{ calculate} = \frac{(k-1)[k \sum_j^k C_j^2 - (\sum_j^k C_j)^2]}{k \sum_i^n R_i - \sum_i^n R_i^2} = \frac{(23-1)[23 \times 484 - (104)^2]}{23 \times 104 - 2182} = 33.104 .$$

With  $\alpha = 0.05$ , degree of freedom (dk) = 23-1 = 22, then obtained Q table (0.05, 22) = 33.924.

With the result above, the decision was made to accept  $H_0$  because  $Q$  was calculated  $(33.104) < Q$  table  $(33.924)$ .

*Table 1. Support questionnaire II table.*

Sub Criteria	Respondent					Cj	Cj <sup>2</sup>
	1	2	3	4	5		
1	1	1	1	1	1	5	25
2	1	1	1	1	1	5	25
3	1	1	1	1	1	5	25
4	1	1	1	0	1	4	16
5	1	1	1	0	0	3	9
6	1	1	0	0	1	3	9
7	1	1	1	1	1	5	25
8	1	1	1	1	1	5	25
9	1	1	1	1	1	5	25
10	1	1	1	1	1	5	25
11	1	1	1	0	0	3	9
12	1	1	1	1	1	5	25
13	1	1	1	1	1	5	25
14	1	1	1	1	1	5	25
15	1	1	1	1	1	5	25
16	1	1	1	1	1	5	25
17	1	1	1	1	0	4	16
18	1	1	1	1	1	5	25
19	1	1	1	1	1	5	25
20	1	1	1	1	1	5	25
21	1	1	1	1	1	5	25
22	1	1	0	1	1	4	16
23	1	1	0	0	1	3	9
R1	23	23	20	18	20	104	484
R1 <sup>2</sup>	529	529	400	324	400	2182	

The conclusions obtained from this result are that all the sub criteria used in the questionnaire is valid because the agreement or equation in the questionnaire shown from the total  $Q$  is smaller than the  $Q$  table.

– Reability test:

Reliability testing is performed using the re-measurement method. The distance between the first measurements and the second measurements with the 15 day period and the questionnaire used in this test i using questionnaire II. The first and second measurements were then tested again using the chi square technique. The difference between the first questionnaire and the second questionnaire is:

**Table 2.** Comparison of questionnaire I and II.

	Measurement I	Measurement II	TOTAL
Yes	111	104	215
No	4	11	15
	115	115	230

x<sup>2</sup> value was known:

$$\begin{aligned}
 x^2 &= \frac{230 [(111 \times 11) - (104 \times 4) - (230/2)]^2}{(111+104)(4+11)(111+4)(104+11)} \\
 &= \frac{230 (1221 - 416 - 115)^2}{215 \times 15 \times 115 \times 115} \\
 &= \frac{230 (690)^2}{42.650.625} \\
 &= \frac{109.503.000}{42.650.625} \\
 &= 2,5674.
 \end{aligned}$$

With an important level of 5% and df = 1, the critical number x<sup>2</sup> is obtained. Because the x<sup>2</sup> value obtained is smaller than the critical value, H<sub>0</sub> is accepted and it is arguable that the questionnaire is reliable.

– Consistency test:

Questionnaire III of all respondents is then combined by using the geometric average formula:

Geometric Average = (z<sub>1</sub>.z<sub>2</sub>.z<sub>3</sub>.....z<sub>n</sub>)<sup>1/n</sup> (4). The results of the geometric mean matrix are:

**Table 3.** Geometric average matrix results.

	Company Condition	Price of Product	The completeness of document	Quality	Services
Company condition	1	0.62	0.72	0.16	0.62
Price of Product	1.61	1	1.35	0.49	1.66
The completeness of document	1.40	0.74	1	0.66	0.70
Quality	6.36	2.05	1.52	1	4.19
Services	1.61	0.60	1.43	0.24	1
Total	11.97	5.01	6.01	2.54	8.17

From the results of the Table 3, normalization is carried out with the formula:

$$\text{Normalization of Matrix: } \frac{\text{point comparisons of criteria}}{\text{Number of Criteria columns}} \quad (5)$$

Normalization of matrix result are:

*Table 4. Normalization of matrix.*

	<b>Company Condition</b>	<b>Price of Product</b>	<b>The Completeness of document</b>	<b>Quality</b>	<b>Services</b>
Company Condition	0.08	0.12	0.12	0.06	0.08
Price of Product	0.13	0.20	0.22	0.19	0.20
The Completeness of document	0.12	0.15	0.17	0.26	0.09
Quality	0.53	0.41	0.25	0.39	0.51
Services	0.13	0.12	0.24	0.09	0.12

Results from the Table 4 return each criterion to be normalized with the results:

*Table 5. Normalization of each matrix criteria.*

	<b>Company Condition</b>	<b>Price of Product</b>	<b>The Completeness of document</b>	<b>Quality</b>	<b>Services</b>	<b>Average</b>	<b>Weight</b>
Company Condition	0.08	0.12	0.12	0.06	0.08	0.46	0.09
Price of Product	0.13	0.20	0.22	0.19	0.20	0.95	0.19
The Completeness of document	0.12	0.15	0.17	0.26	0.09	0.78	0.16
Quality	0.53	0.41	0.25	0.39	0.51	2.10	0.42
Services	0.13	0.12	0.24	0.09	0.12	0.71	0.14
TOTAL						5.00	1.00

From Table 5, the consistency test is performed with the following steps:

- Average geometry for the total criteria of the company's conditions are:

$$0.08+0.12+0.12+0.06+0.08 = 0.46.$$

- Local weights for company condition criteria are:

$$\frac{0.46}{5} = 0.09.$$

–  $\lambda$  max:

$$(0.09 \times 11.97) + (0.19 \times 5.01) + (0.16 \times 6.01) + (0.42 \times 2.54) + (0.14 \times 8.17) = 5.23.$$

– Index of consistency :  $CI: \frac{5.23-5}{5-1} = 0.06.$

– Ration of consistency :  $CR: \frac{0.06}{1.12} = 0.05.$

Because CR is less than 0.1, the respondents' criteria of assessment can be said to be consistent and weight can be used for comparison of criteria.

– Calculation of constants per supplier:

The IV questionnaires that have changed in the form of liberative standard are:

**Table 6.** The IV questionnaires result.

Supplier	Respondent	Company condition	Price of product	The completeness of document	Quality	Services
PT. ABC	Respondent 1	0.129	0.513	0.129	0.261	0.129
	Respondent 2	0.261	0.261	0.129	0.129	0.129
	Respondent 3	0.129	0.261	0.129	0.129	0.129
	Respondent 4	0.513	0.261	0.129	0.261	0.129
	Respondent 5	0.261	0.129	0.261	0.261	0.261
PT. DEF	Respondent 1	0.129	0.261	0.261	0.261	0.261
	Respondent 2	0.261	0.129	0.261	0.129	0.129
	Respondent 3	0.129	0.261	0.129	0.129	0.129
	Respondent 4	0.513	0.261	0.129	0.261	0.129
	Respondent 5	0.261	0.129	0.129	0.129	0.261
PT. GHI	Respondent 1	0.129	0.129	0.129	0.129	0.129
	Respondent 2	0.261	0.129	0.261	0.129	0.129
	Respondent 3	0.129	0.129	0.129	0.129	0.129
	Respondent 4	0.261	0.129	0.129	0.261	0.129
	Respondent 5	0.261	0.261	0.129	0.129	0.129
PT. JKL	Respondent 1	0.129	0.129	0.261	0.129	0.129
	Respondent 2	0.261	0.129	0.261	0.129	0.129
	Respondent 3	0.129	0.129	0.129	0.129	0.129
	Respondent 4	0.063	0.063	0.034	0.063	0.034
	Respondent 5	0.261	0.261	0.129	0.261	0.129
PT. MNO	Respondent 1	0.129	0.129	0.129	0.129	0.129
	Respondent 2	0.261	0.129	0.261	0.129	0.129
	Respondent 3	0.063	0.129	0.063	0.063	0.063
	Respondent 4	0.034	0.034	0.063	0.034	0.034
	Respondent 5	0.129	0.261	0.129	0.261	0.261

The results in Table 6 are then combined using the fourth equation and are normalized with the result:



**Table 7.** Normalization of average geometric supplier.

	PT. ABC	PT. DEF	PT. GHI	PT. JKL	PT. MNO	Weight of criteria
Company condition	0.230	0.241	0.255	0.233	0.189	0.093
Price of product	0.265	0.211	0.193	0.203	0.218	0.191
The completeness of document	0.152	0.183	0.193	0.206	0.214	0.155
Quality	0.201	0.183	0.193	0.203	0.189	0.420
Services	0.152	0.183	0.167	0.156	0.189	0.142
TOTAL	1.000	1.000	1.000	1.000	1.000	1.000

- Weighting between criteria with supplier:

The results in Table 7 are then compared to the weight of the criteria in Table 5 and are used by the overall composite table with the result:

**Table 8.** Overall composite table.

	PT. ABC	PT. DEF	PT. GHI	PT. JKL	PT. MNO
Company condition	0.021	0.022	0.024	0.022	0.018
Price of product	0.051	0.040	0.037	0.039	0.042
The completeness of document	0.024	0.028	0.030	0.032	0.033
Quality	0.084	0.077	0.081	0.085	0.079
Services	0.022	0.026	0.024	0.022	0.027
TOTAL service value	0.2014	0.1935	0.1948	0.1993	0.1986

#### 4. Result

- Supplier criteria weight analysis:

Based on Table 5, it can be seen that the largest weight is obtained with quality criteria with the number of points 0.42. The value command explains the evaluation of each criterion so that the larger value contained in this criterion shows more influencing this criteria for this study.

- Analyze the weight of each supplier:

From Table 8, suppliers are segregated from highest to lowest value. In this case PT. ABC has the largest value of 0.2014 which means suppliers' comparison with the weight of existing criteria has the highest influence over other suppliers.

## 5. Conclusion and Recommendations

PT ABC has the highest ratings in supplier ratings that were directly compared to the existing weight, so that it can be prioritized in getting the Tugboat Gearbox spare parts. From the criterion assessment results that must be supplied by the supplier, the highest weight was obtained by the quality factor. The Company as a supplier employer should immediately assess some of the criteria in question and make this criterion as the key performance indicator (s) of the questionable supplier, in which the routine or assessment of the vendor's evaluation is conducted periodically. It is expected to make suppliers' estimates for all supplier-related employees so that the appraisal results are more accurate and obtain more comparisons.

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