Designing Model of Spare Parts Supplier Selection in Power Plants Using AHP-PROMETHEE Method

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Abstract

The increasing electricity demand and consumption push electricity supply must always be available in maximum capacity. Selection of suppliers is an important process to overcome the risk of failure in procurement, but it is a difficult task because it takes many consideration based on the criteria. This study proposes a selection model of spare parts suppliers in power plants using a combination of Analytical Hierarchy Process (AHP) and Preference Ranking of Organization Method for Enrichment Evaluation (PROMETHEE) method. AHP is used to determine the importance weight of criteria and PROMETHEE to produce a ranking of suppliers. This model is applied to select suppliers for fin tube and solenoid valve. Results show that Supplier D, which has the shortest lead time even not the lowest price, is selected out of four suppliers for fin tube and Supplier E, which has the lowest price with the shortest lead time, is selected from three suppliers for solenoid valve. This paper also tests 3 number of scenarios against the model.

Keywords
Supplier Selection, Spare Part, Power Plant, AHP, PROMETHEE

1. Introduction

Electricity is crucial nowadays. In Indonesia, consumption per capita continues to increase each year which is also in line with the increase in the electrification ratio. By June 2018 the achievement of the electrification ratio is at 97.50%. In maintaining electricity production in Indonesia, operations and maintenance activities are carried out at the power plant. Supply Chain Management (SCM) activities facilitate operations and maintenance for a power plant. The procurement process is a vital process in SCM because it is the spearhead of the whole process (Rozi & Herowati, 2018).

Supplier selection is the most important activity in the procurement department (Sun, Xie, & Xue, 2005), while the success of a supply chain system greatly effect the selection on the selection of good suppliers. Selection of suppliers in the procurement process can reduce the risk of procurement failure that will affect other processes. But, the selection of suppliers is difficult because it must consider both qualitative and quantitative criteria (Hanane, Brahim, & Bouchra, 2015). The integration development model of AHP and PROMETHEE is proposed to select spare parts suppliers for power plants.

2. Literature Review

2.1. Supplier Selection

The success of a supply chain system has significant impact on the selection of good suppliers (Chung, 2015). In the context of a business competition environment, supplier selection and evaluation process plays important role in the performance of a company. Supplier selection is the process where suppliers are reviewed, evaluated, and selected to be part of the organization's supply chain (Mukherjee, 2017). The main objectives of supplier selection are to minimize purchasing risk, maximize value for buyers, and build close and long-term relationships between buyers and suppliers. However, the process of selecting suppliers can be time-consuming and requires resources to collect data and perform careful analysis of a variety of positive and negative factors that will affect all alternative decisions (Ávila, Mota, & Pires, 2012).

2.2. Power Plant Component

The reliability of the plant supports the performance of the power plant business, and to achieve this reliability, relevant operations and maintenance activities are carried out in order to achieve the appropriate level of utilization (Terziovski, 2014). If there is damage to the power plant it can have an impact on the lack of electricity for the community (Sabouhi, Abbaspour, Fotuhi-firuzabad, & Dehghanian, 2016). In the Combined Cycle power plant, gas turbines, steam turbines, and Heat Recovery Steam Generator have an important role to generate electricity and have critical components that can affect the failure of power plants (Kannan, Amirthagadeswaran, Christopher, & Rao, 2013). Each machine is composed of parts. Spare parts are needed because they are a factor that ensures the operation of the power plant can run sustainably and safely (Liu, Jiang, & Liu, 2014).

2.3. Multi Criteria Decision Making (MCDM)

MCDM is a method used to show or rank a number of limited alternatives by considering several criteria related to alternatives (Abdullah, 2018). The MCDM method is often used in supplier selection. AHP, one of MCDM method, considers a set of evaluation criteria, and a set of alternative choices between the best decisions to be made.

2.4. Analytical Hierarchy Process (AHP)

AHP generate weights for each evaluation criterion in accordance with the comparison of the decision-maker criteria. The higher the weight, the more important are the criteria. There are three AHP principles, first is decomposition, which breaks the whole problem into interconnected elements, in the form of a hierarchical structure. The second is comparative judgment, by giving weight to the criteria in paired comparison matrix with a quantitative 9-scale to assess the comparison of the level of importance of an element to other elements. The third is logical consistency, which the results of the assessment accepted if the maximum inconsistency ratio is 10% (Saaty, 1987).

2.4. Preference Ranking of Organization Method for Enrichment Evaluation (PROMETHEE)

PROMETHEE is an outranking method in MCDM. PROMETHEE ranks all alternatives by comparing them with other alternatives by considering each criterion so that decision-makers can prioritize the best alternative(Bongo, Alimpangog, Loar, Montefalcon, & Ocampo, 2018). PROMETHEE has 6 different preference functions for generalized criteria proposed by Brans. PROMETHEE I is for partial alternative ranking and is usually followed by PROMETHEE 2 for a complete comparison

3. Methods

Literature study is carried out from research papers that have been previously published to obtain criteria for this study. All existing criteria and sub-criteria have been validated by experts, where criteria with values above the threshold will be used in this study. AHP is used to find the weight of the criteria that have been obtained previously by doing a pairwise for the opinion of experts (Dachyar & Purnomo, 2018). PROMETHEE is used in rating suppliers according to supplier capabilities and performance based on existing criteria.

3.1. Selection of Criteria

From the previous papers, regarding the selection of suppliers in the power plant and for spare parts, 5 criteria and 22 sub-criteria are obtained. There are 8 experts from both the procurement department and users who assess selection criteria. The criteria will be used if its average score is above 3,44 from 5 scales. Overall, 5 criteria and 19 sub-criteria are used for the next stage. The criteria and sub-criteria are shown in Figure1.

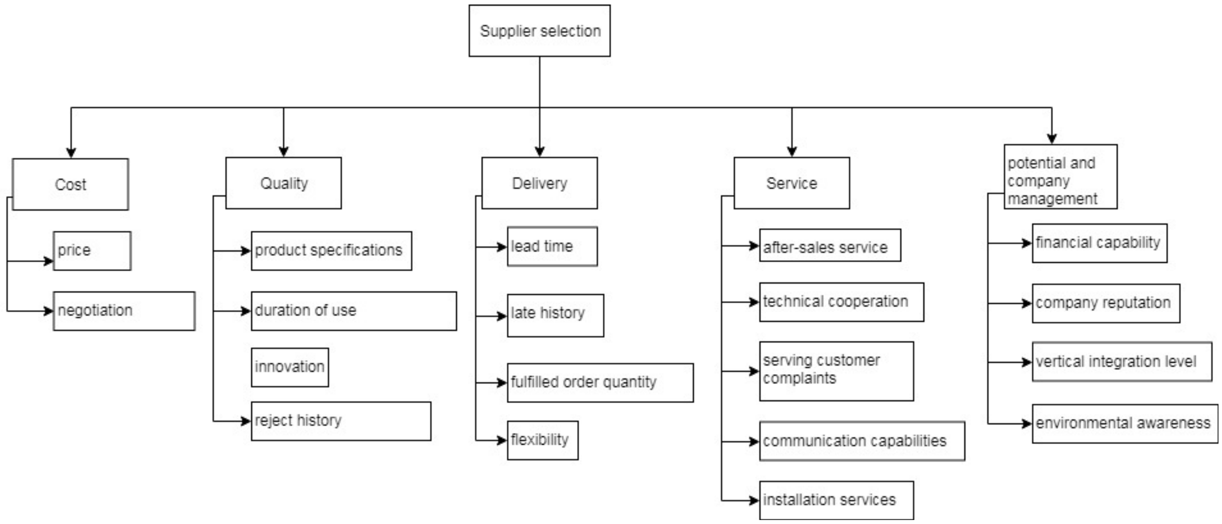

Figure 1. Hierarchy of selected criteria and sub-criteria

3.2. Weighting Criteria

Weight is calculated using AHP application; Expert Choice. The questionnaire contains Pairwise comparisons with a 9-scale measurement between sub-criteria in the same criteria that are carried out by experts from 3 power plant units in Indonesia. After obtaining the weights, consistency ratio (CR) is calculated to ensure that expert opinion is consistent. Inconsistency must be less than 10%, and after calculated all matrix in this research got less than it as shown in Table 1. The weight of the sub-criteria will be used in PROMETHEE. The final weight of each sub-criteria is shown in Figure 2.

Table 1 Inconsistency Ratio of criteria and sub-criteria

Name	Inconsistency Ratio
Supplier selection criteria	0,07
Price	0,00
Quality	0,07
Delivery	0,04
Service	0,03
Potential and company management	0,07

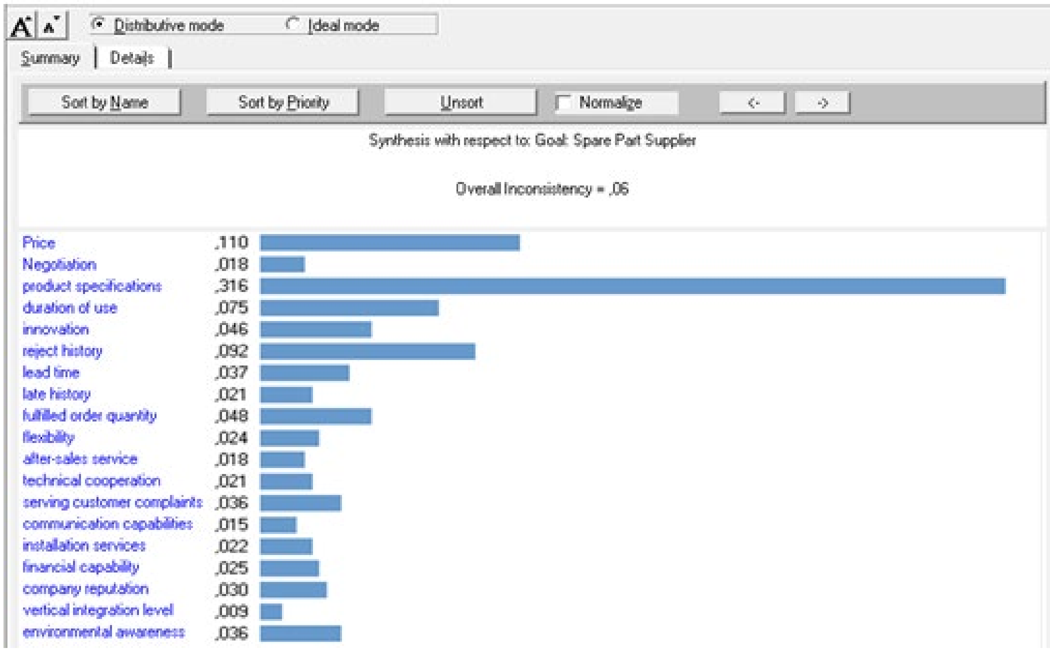

Figure 2 Final weight of each sub-criteria

3.3. Alternative Selection

PROMETHEE is used to find out the supplier ratings. Supplier capability and performance are calculated from the criteria that have been determined. The use of criteria type, function preference type and a parameter for each criterion is determined by experts, which can be seen in Table 2.

Table 2 Preference function

Criteria	Max/Min	Preference Type	Q	P
C1	Min	5	20	100
C2	Max	1		
C3	Max	1		
C4	Max	3	0,09	
C5	Max	1		
C6	Min	3	2	
C7	Min	3	0,25	
C8	Min	3	30	
C9	Max	1		
C10	Max	1		
C11	Max	1		
C12	Max	1		
C13	Max	1		
C14	Max	1		
C15	Max	1		
C16	Max	1		
C17	Max	1		
C18	Max	1		
C19	Max	1		

Alternatives value are compared one by one so that the deviation value is obtained. These deviations are normalized by generating a preference function. The total value of the criteria preference function for each alternative is called aggregated preference index. Outranking flows that are generated both leaving flow and entering flow give a partial rating and net flow. Net flow on PROMETHEE II provides a complete ranking. Calculation results of leaving flow, entering flow, and net flow for fin tube suppliers can be seen in Table 2, while for solenoid valve suppliers in Table 3.

Table 3 Leaving flow, entering flow, and net flow result for fin tube

Supplier	$Leaving\ flow\ (\emptyset^{+})$	$Entering\ flow\ (\emptyset^{-})$	*Net flow (∅ (i))*
A	0,14	0,13	0,01
B	0,08	0,16	-0,08
C	0,13	0,10	0,02
D	0,13	0,08	0,05

Table 4 Leaving flow, entering flow, and net flow result for solenoid valve

Supplier	$Leaving\ flow\ (\emptyset^{+})$	$Entering\ flow\ (\emptyset^{-})$	*Net flow (∅ (i))*
E	0,16	0,03	0,13
F	0,05	0,08	-0,03
G	0,01	0,11	-0,10

Partial ranking for fin-tube supplier selection are aP^1b, cP^1b, dP^1b, $dP^1c, aR^1c, aR^1d, cR^1a, dR^1a$, shows that supplier A, C, D is better than supplier B, and supplier D is better than supplier C. While for complete ranking, supplier D is better than supplier C, which is better than supplier A, while supplier B has the lowest score. Supplier C is selected as the best choice for fin tube since it has the shortest lead time even if it doesn't have the lowest Price.

Partial ranking for solenoid valve supplier selection are eP^1f, eP^1g, fP^1g, shows that supplier E is better than supplier F and G, and supplier F is better than supplier G. Supplier E is selected as the best choice, with the shortest lead time, even if it has a delay history.

4. Results and Discussion

The model previously created is the base model developed under normal condition. This study will test several posible scenarios against the model. There are four scenarios used in this study. Scenario 1 is when all preference types used are replaced with the preference type 1 (Usual Criterion). Scenario 2 is when there is sudden damage to certain parts that force the plant unit to borrow parts from other units first and return them as soon as possible. This increases the importance weight of lead time, so that the lead time weight is increased. Scenario 3 is when the lead time criteria are assessed during the screening stage at the beginning, so suppliers whose lead time exceeds the desired value will be blacklisted and the criteria for lead time weights are no longer calculated for ranking. The result for fin tube is shown in Tabel 3, and for solenoid valve is shown in Tabel 4.

Table 5 Scenario result for fin tube supplier

Ranking	Normal	Scenario 1	Scenario 2	Scenario 3
1	D	C	D	C
2	C	D	C	D
3	A	A	B	B
4	B	B	A	-

Table 6 Scenario result for solenoid valve supplier

Ranking	Normal	Scenario 1	Scenario 2	Scenario 3
1	E	E	E	E
2	F	G	F	F
3	G	F	G	G

From the results of scenario 1, it can be seen that the preference function greatly influences the results. In scenario 1, Supplier D is less preferred than Supplier C because supplier D does not offer the lowest price. In the normal condition of price preference function value, supplier D is not absolutely defeated against C price preference, but preference function in type 1 will only give preference function value 1 or 0 then supplier C has full value for the price criterion.

The results of scenarios 2 raise supplier B's rank to the third, since B has shorter lead time than supplier A. For solenoid valve supplier, the ranking is the same as in the normal condition.

From the result of scenario 3 for selecting fin tube supplier, supplier A is blacklisted because the lead time exceeds the specified one. Supplier C initially has a longer lead time from suppliers D and B, but because the lead time weight is no longer used for ranking, as long as it does not exceed the standard, supplier C becomes the most preferred choice. The order of solenoid valve suppliers has not changed in scenario 3.

5. Conclusion

The integration model is developed using AHP-PROMETHEE method. Five criteria with 19 sub-criteria to select spare parts suppliers for the power plant are obtained . The most important sub-criteria is product spesification. A case study was conducted for selecting fin tube and solenoid valve suppliers. The best results for fin-tube suppliers are suppliers D with the shortest lead times, even though not the cheapest. Best supplier for solenoid valve was supplier E which has the lowest price with the shortest lead time. From the 4 scenarios carried out in this study scenario 1 changes the order of fin tube and solenoid valve suppliers, scenarios 2 change the order of fin tube suppliers but not with solenoid valve supplier. Scenario 3 reduces the supplier's proposal and changes the order of the fin tube supplier but not on the solenoid valve.

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