Integration of AHP and DEA Methods for Supplier Selection

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Integration of AHP and DEA Methods for Supplier Selection

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Abstract: The smooth production process and product availability are very important in every company, in order to meet customers' timely, quantitative, and qualitative demands. This research therefore aims to select suppliers appropriately by considering various criteria to ensure the smooth running of the production process or product availability. Analytical Hierarchy Process (AHP) was used as integration method to weight the criteria and sub-criteria used by the company (output variable in DEA Method). Data Envelopment Analysis (DEA) was used to choose an efficient supplier. The results showed that three suppliers are efficient. Therefore, to determine the best supplier, AHP was used to weigh criteria and sub-criteria used by the company (efficient supplier's input variable in DEA Method). This method resulted in supplier B as the chosen supplier.
Keywords: Supplier Selection, AHP, DEA

I. INTRODUCTION

Manufacturing companies need to operate an effortless production process in order to meet the demands of customers. Similarly, distributing companies need to ensure prompt availability of products in accordance with its quantity and quality. To achieve these, the most efficient suppliers of raw materials are needed. However, this is a difficult task, considering the fact that these suppliers also have certain advantages and disadvantages in terms of satisfying the requirements of the company. Therefore, they need to determine the right criteria according to their analysis(1).

The decision to purchase raw materials and finished products is important for sustainability due to the operational costs of over 50% of the selling price incurred by the company (2). In accordance with this, the supplier plays an important role in the production process and in the procurement of finished products. Therefore, the right suppliers are determined based on those that meet the criteria set by the company, and they have an impact on customer satisfaction (3). However, this selection process is rather complicated, considering the huge number of suppliers, and they often do not meet some of the criteria set by the company. Based on these, a calculation model that helps to make the selection process easier and more precise is required. This research therefore focuses on the various criteria derived from previous studies, and it is aimed at ensuring a proper assessment process. In addition, the calculations in this study employed two methods, namely AHP and DEA methods. AHP is used as weighing criteria and sub criteria in DEA method output variable. And then DEA Method to measure suppliers' efficiency. AHP is then used again to weigh supplier's input variable efficiency and determine the best supplier.

II. LITERATURE REVIEW

2.1. Supplier Selection

The supplier provides resources, for both goods and services needed by other groups (4). They play an important role in a company and ensure appropriate selection process which aids in choosing the right supplier as well as reduce the cost of purchasing raw materials or finished products needed by the company (4).

The purpose of this process is to enable companies to carry out a systematic selection process in identifying, prioritizing, and evaluating the criteria deemed necessary (5). Furthermore, prospective suppliers need to meet the set criteria. It is difficult to determine suppliers that meet all the criteria set by the company. Therefore, in order to resolve this issue, it is important to weigh the commodities to ensure it is used as a reference for assessing potential suppliers (6).

2.2. Analytical Hierarchy Process (AHP)

The analytical hierarchy Process is a method used in decision making for complex problems. However, it was initially suggested by Dr. Thomas L. Saaty from Wharton School of Business in 1970 (7).

The AHP weighs each criterion (6). It is also used to analyze complex problems by breaking it down into hierarchies in order to achieve more structured and systematic results (8).

According to a research conducted by Simanungkalit (8), a decision support system can be used to propose an alternative selection process, because the companies had always chosen suppliers subjectively. The variables used in this study are price, quality, and service. Furthermore, a journal entitled Analysis of Rice Supplier Selection by Rohimat (3) employed the analytical hierarchy process (AHP) using quality, price, flexibility, delivery, and responsiveness as the criteria for determining the best performance of the suppliers that consistently met the needs of the company. Similar research on criteria and performance evaluation of the suppliers was also conducted by Zahir, S.M (7). It employed certain variables such as quality, durability, delivery, price, responsiveness, financial, and business stability. In addition, the variables for information on process development, technical ability, and good background.

Analytical hierarchy process (AHP) and heuristic algorithm methods were used to select vendors, and they served as a Multi-Criteria Decision Making (MCDM) problem (5). The three variables used are price, quality, and delivery. They were also employed in another research conducted by Gjosh, T, Chakraborty, T, and Dan, P.K. (9) concerning the selection of suppliers using the Analytical Hierarchy Process (AHP) and Metaheuristic Algorithm methods.

2.3. Data Envelopment Analysis (DEA)

Data Envelopment Analysis is an appropriate decision-making method for assessing the efficiency of suppliers (10). It is used to compare their performance by the company, and an effective approach used to prove the overall efficiency of suppliers (10). In addition, DEA is used to measure the effectiveness of Decision Making Units (DMUs), used to produce several outputs, such as goods or services (11).

According to studies conducted by Cahya, M.I., Setiawan, H. and Ummi, N. (1), it aimed to choose efficient suppliers as partners. The input criteria are price and entire shipment while output and sub-criteria are services (such as fast response service, explanation of product quality, ready stock), payment (time of payment, installments without interest), guarantee (time of guarantee, conditions of requesting warranty, form of replacement of goods under warranty), and delivery (such as time of delivery, safety of goods in shipment, determination of the number of goods delivered).

A similar study was also carried out by (12), concerning the efficiency of supply chain performance using the DEA analysis with the assumption of constant return to scale (CRS). The input variables used are order fulfillment cycles, supply chain flexibility, total supply chain costs, cash to cash cycle time, and daily inventory, while, the output variables are delivery performance, shipment fulfillment, and compliance with standards. Additionally, another research was conducted by Rambe, I.H., and Syahputra, M.R. (13), on the application of Data Envelopment Analysis (DEA) to measure the efficiency of production activities. The DEA method used is the Primal CCR model, to determine which UPK (Decision Making Unit) is effective and which is inefficient. The input variable is the amount of labour, the number of hours spent on production, and the cost of raw materials. Furthermore, the output variables consist of the number of customers and products. Conversely, a similar study was also carried out by Suryani, L. and Setyaningsih, I., (14), to measure the performance of suppliers using the Data Envelopment Analysis (DEA) Method, input and output criteria. The input and output data are the total purchase price and ability to meet the ordered, shrimp, delivery performance, and track record.

2.4. AHP and DEA Integration

Some studies integrate DEA and AHP methods, such as researches conducted by Darmawan, H., Setiawan, H. and Sirajuddin, S., (15), to measure the performance of suppliers. The variables used are price, quality, delivery performance, warranty, and shipment fulfillment. The value of the output criteria is obtained through weighting, which is calculated using the Analytical Hierarchy Process (AHP) method. However, other research that employed a combination of the two methods was conducted by Harlawan, M.G., Ridwan, A.Y. and Kenaka, S.P., (16). The problem always faced by companies is the continuous change of suppliers because they do not last in the long run. Therefore, a decision support system was designed to aid in supplier selection by considering various qualitative and quantitative criteria. AHP is used to measure the value or qualitative variables however the criteria used are price, quality, conformity of specifications, after-sales, service, manufacturing capability, and environment.

According to a research carried out by Lim, J.J., and Zhang, A.N., (10), a combination of these methods was also employed and the variable used considered the risk factors. The study stated that the selection

of the right supplier is not only based on price, however, many criteria also need to be considered, both quantitatively and qualitatively. Furthermore, the variable supply risk in supplier evaluation needs to be included. The variables used in the study are quality, service, reputation, management, environment, and risk.

In a study conducted by Sánchez, M.A. (11), both methods were employed to monitor the project performance in terms of economic, environmental, and organizational goals. The results from this research showed that the DEA approach is appropriate for monitoring projects and to discuss all possible modifications and additions to be made using AHP.

Veni, K.K., Rajesh, R., and Pugazhendhi, S., (2), reported that interconnected and competitive companies need to select suppliers effectively. This means that the effectiveness of supplier selection is important because the process is a multi-criteria problem that needs to be resolved appropriately. The variables or criteria used in this study are costs, supplier profiles, risk management, long-term cooperation, and services.

According to Diouf, M., and Kwak, C. (17), it is important to appropriately choose suppliers needed by companies, however, due to certain conditions, the assessment is not fully used as a reference. The research stated that supplier development acts as an alternative. The managerial analysis needs to be proposed in order to assess the impact of the criteria used, which are quality, price, delivery, flexibility, technology capability, trustworthiness, financial capability, and customer service.

The research conducted by Mahapatra, B., Mukherjee, K. and Bhar, C., (18), reported that a combination of the two methods mentioned earlier, led to the development of an application model employed to measure the performance of the organization, using costs (both the cost of raw materials and operational) as the input variable and profit rate as the output criteria.

A similar study was conducted by Pakkar, M.S., (19), and it stated that a combination of both methods tends to be used to measure the performance of the Decision-Making Unit while the appropriate weighing needs to be carried out in order to produce a good assessment. The research carried out by Akbarian, D. (20) presents an approach that measures the efficiency of the Decision-Making Unit (DMU) with DEA by weighing using AHP. Basically, this study aims to compare other approaches.

III. RESEARCH METHOD

3.1. Criteria used in research

This research employed criterias and sub-criterias obtained from previous studies to determine the best supplier.

Table 1. Criteriasand Sub Criterias for Supplier Selection

Criteria	Sub Criteria	Literary Sources
Price	Price Match	Criteria : [1],[7],[8],[15],[16],[17] Criteria and Sub Criteria : [3]
	Discount Percentage	
Delivery costs	Delivery Costs	Criteria and Sub Criteria : [2],[5],[9]
Lead Time	Lead Time	Criteria and Sub Criteria : [12]
Quality	Suitability of the Goods with the Specified Specifications	Criteria : [3],[5],[7],[8],[9],[10],[12],[14],[17]
	Supply of goods without defects	Criteria and Sub Criteria : [3],[15],[16]
Delivery	Punctual Delivery	Criteria : [5],[7],[9],[12],[14],[17] Criteria and Sub Criteria : [1],[3],[15]
	Accuracy in Amount in Delivery	
	Safety of Goods in Shipment	
	Continuity of Delivery	
Service	Contactability	Criteria : [2],[7],[8],[10],[16] Criteria and Sub Criteria : [1],[3]
	Fast Response Service	
	Explanation of the Quality of Goods	
	Ready Stock	
Flexibility	Ease of Adding / Reducing Number of Orders	Criteria : [12],[17] Criteria and Sub Criteria : [3]
	Ease of Changing Delivery Time	
Payment	Can be paid in installments	Criteria and Sub Criteria : [1]
	Payment Time	
	Interest-free installments	
Guaranty	Time of Guaranty	Criteria and Sub Criteria : [1],[15]
	Conditions for Requesting Guaranty	
	Form of Replacement of Goods Under Guaranty	

3.2. Analytical Hierarchy Process (AHP)

Analytical Hierarchy Process as reported by Saaty, (21)shows the importance of the assessment in table 1.

Table 2. The Fundamental Scale of Absolute Numbers

Value A	Definition	Value B	Definition
1	A is equal importance than B	1	B is equal importance than A
3	A is moderate importance than B	1/3	B is moderate importance than A
5	A is strong importance than B	1/5	B is strong importance than A
7	A is veru strong importance than B	1/7	B is veru strong importance than A
9	A is extreme importance than B	1/9	B is extreme importance than A
2,4,6,8	Intermedite Value, if there is doubt between 2 values A can choose the middle value between the two values	1/2, 1/4, 1/6, 1/8	Intermedite Value, if there is doubt between 2 values B can choose the middle value between the two values

Consistency (5)

$$CR = \frac{CI}{RI} \quad (1)$$

$CR \leq 0.1$

CR = Consistency Rasio

RI = Random consistency Index

CI = Consistency Index

3.3. Data Envelopment Analysis (DEA)

General form DEA (16)

$$Max\ hj = \sum_{r=1}^{s} UrYrj$$

$$Subject\ to: \sum_{i=1}^{m} ViXij = 1$$

$$\sum_{r=1}^{s} Ur\ Xrj - \sum_{i=1}^{m} Viij \leq 0$$

Ur, Vi ≥ 0

4. SIMULATION CASE

4.1. Weighting Using the AHP Method

Table 3 shows the quantitative data such as price, shipping costs, and lead time (Input Variable in DEA Method) for each supplier A, B and C, which areconsidered to be suppliersof the company

Table3. Prices, Delivery Costs and Lead Time

Criteria	Supplier 1	Supplier 2	Supplier 3
Price (Rp per unit)	Rp 20,000.00	Rp 18,000.00	Rp 17,000.00
Shipping costs (Rp per order)	Rp 400,000.00	Rp 300,000.00	Rp 550,000.00
Lead Time (days)	2	4	6

Table4 is an assessment of the criteria (Output Variable in DEA Method) using the guidelines contained in table 1.

Table 4. Criteria Assessment Table

	Quality	Shipment	Service	Flexibility	Payment	Guaranty
Quality	1	5	5	6	5	5
Shipment		1	3	2	3	2
Service			1	3	4	1
Flexibility				1	0.50	0.33
Payment					1	0.50

Furthermore, assessment and supplier evaluation are carried out for each sub-criterion. The weights of each criterion and sub-criteria are calculated for each supplier. Tables 5 and 6 are tables that shows the weighting for each criterion and sub criteria, as well as their supplier ratings

Table 5. Weight of Criteria and Sub Criteria

No	Criteria and Sub Criteria	Weight
1.	**Quality**	**0,483**
	a. Compliance of goods with the specifications set	0,121
	b. Supply of goods without defects	0,362
2.	**Shipment**	**0,176**
	a) On time delivery	0,077
	b) Accuracy in the amount of delivery	0,055
	c) Security of goods in shipping	0,026
	d) Continuity of delivery	0,018
3.	**Service**	**0,121**
	a. Ease of contact	0,033
	b. Fast response service	0,061
	c. Explanation of product quality	0,011
	d. Ready Stock	0,017
4.	**Flexibility**	**0,051**
	a) Ease of adding / reducing the number of orders	0,038
	b) Ease of changing the delivery time	0,013
5.	**Payment**	**0,062**
	a. Can be paid in installments	0,014
	b. Time of payment	0,008
	c. Installments without interest	0,040
6.	**Guaranty**	**0,107**
	a) Time of guaranty	0,011
	b) Requirements for guaranty	0.028
	c) The form of replacement of goods under guaranty	0,068

Table 6. Weighting of Each Criteria For Each Supplier (Output)

No	Criteria and Sub Criteria	*Supplier* 1	*Supplier* 2	*Supplier* 3
1.	Quality	0,250	0,646	0,104
2.	Shipment	0,239	0,226	0,535
3.	Service	0,269	0,547	0,184
4.	Flexibility	0,242	0,643	0,115
5.	Payment	0,578	0,312	0,110
6.	Guaranty	0,218	0,633	0,149

The calculation is further continued by employing the DEA modeling.

4.2. DEA Modeling

Table 7 shows the Input values (quantitative value) and Output weighting (using the AHP method), which are then included in the DEA method modeling, and the efficiency values are obtained.

Table 7. Weighting of Outputs and InputsVariable Values in DEA

Supplier	Variable Input				Variable Output				
	Price (I_1) (Rp per unit)	Delivery costs (I_2) (Rp per order)	Lead Time (I_3) (days)	Quality (O_1)	Delivery (O_2)	Service (O_3)	Flexibility (O_4)	Payment (O_5)	Guaranty (O_6)
***Supplier* 1**	Rp 20,000.00	Rp 400,000.00	2	0,250	0,239	0,269	0,242	0,578	0,218
***Supplier* 2**	Rp 18,000.00	Rp 300,000.00	4	0,646	0,226	0,547	0,643	0,312	0,633
***Supplier* 3**	Rp 17,000.00	Rp 550,000.00	6	0,104	0,535	0,184	0,115	0,110	0,149

Afterwards, input and output variables value on table 7 are measured on DEA model. Since there are 3 suppliers, 3 DEA models are needed to maximize each supplier's variable output. While constrains consist of:

supplier's efficiency (ratio between input and output variable), supplier's input variable value, and non-negative requirement.

Supplier Model 1
Function :
Max Z : $0{,}250\ O_1 + 0{,}239\ O_2 + 0{,}269\ O_3 + 0{,}242\ O_4 + 0{,}578\ O_5 + 0{,}218\ O_6$
Constrain :
$0{,}250\ O_1 + 0{,}239\ O_2 + 0{,}269\ O_3 + 0{,}242\ O_4 + 0{,}578\ O_5 + 0{,}218\ O_6 - 20.000\ I_1 - 400.000\ I_2 - 2\ I_3 \leq 0$
$0{,}646\ O_1 + 0{,}226\ O_2 + 0{,}547\ O_3 + 0{,}643\ O_4 + 0{,}312\ O_5 + 0{,}633\ O_6 - 18.000\ I_1 - 300.000\ I_2 - 4\ I_3 \leq 0$
$0{,}104\ O_1 + 0{,}535\ O_2 + 0{,}184\ O_3 + 0{,}115\ O_4 + 0{,}110\ O_5 + 0{,}149\ O_6 - 17.000\ I_1 - 550.000\ I_2 - 6\ I_3 \leq 0$
$20.000\ I_1 + 400.000\ I_2 + 2\ I_3 = 1$
$O_1 \geq 0{,}0001$
$O_2 \geq 0{,}0001$
$O_3 \geq 0{,}0001$
$O_4 \geq 0{,}0001$
$O_5 \geq 0{,}0001$
$O_6 \geq 0{,}0001$
$I_1 \geq 0{,}0001$
$I_2 \geq 0{,}0001$
$I_3 \geq 0{,}0001$

Supplier Model 2
Function :
Max Z : $0{,}2646\ O_1 + 0{,}226\ O_2 + 0{,}547\ O_3 + 0{,}242\ O_4 + 0{,}578\ O_5 + 0{,}218\ O_6$
Constrain :
$0{,}250\ O_1 + 0{,}239\ O_2 + 0{,}269\ O_3 + 0{,}242\ O_4 + 0{,}578\ O_5 + 0{,}218\ O_6 - 20.000\ I_1 - 400.000\ I_2 - 2\ I_3 \leq 0$
$0{,}646\ O_1 + 0{,}226\ O_2 + 0{,}547\ O_3 + 0{,}643\ O_4 + 0{,}312\ O_5 + 0{,}633\ O_6 - 18.000\ I_1 - 300.000\ I_2 - 4\ I_3 \leq 0$
$0{,}104\ O_1 + 0{,}535\ O_2 + 0{,}184\ O_3 + 0{,}115\ O_4 + 0{,}110\ O_5 + 0{,}149\ O_6 - 17.000\ I_1 - 550.000\ I_2 - 6\ I_3 \leq 0$
$18.000\ I_1 + 300.000\ I_2 + 4\ I_3 = 1$
$O_I \geq 0{,}0001$
$O_2 \geq 0{,}0001$
$O_3 \geq 0{,}0001$
$O_4 \geq 0{,}0001$
$O_5 \geq 0{,}0001$
$O_6 \geq 0{,}0001$
$I_1 \geq 0{,}0001$
$I_2 \geq 0{,}0001$
$I_3 \geq 0{,}0001$

Supplier Model 3
Function :
Max Z : $0{,}104\ O_1 + 0{,}535\ O_2 + 0{,}269\ O_3 + 0{,}242\ O_4 + 0{,}578\ O_5 + 0{,}218\ O_6$
Constrain :
$0{,}250\ O_1 + 0{,}239\ O_2 + 0{,}269\ O_3 + 0{,}242\ O_4 + 0{,}578\ O_5 + 0{,}218\ O_6 - 20.000\ I_1 - 400.000\ I_2 - 2\ I_3 \leq 0$
$0{,}646\ O_1 + 0{,}226\ O_2 + 0{,}547\ O_3 + 0{,}643\ O_4 + 0{,}312\ O_5 + 0{,}633\ O_6 - 18.000\ I_1 - 300.000\ I_2 - 4\ I_3 \leq 0$
$0{,}104\ O_1 + 0{,}535\ O_2 + 0{,}184\ O_3 + 0{,}115\ O_4 + 0{,}110\ O_5 + 0{,}149\ O_6 - 17.000\ I_1 - 550.000\ I_2 - 6\ I_3 \leq 0$
$17.000\ I_1 + 550.000\ I_2 + 6\ I_3 = 1$
$O_1 \geq 0{,}0001$
$O_2 \geq 0{,}0001$
$O_3 \geq 0{,}0001$
$O_4 \geq 0{,}0001$
$O_5 \geq 0{,}0001$
$O_6 \geq 0{,}0001$
$I_1 \geq 0{,}0001$
$I_2 \geq 0{,}0001$
$I_3 \geq 0{,}0001$

From these models, optimal solutions are sought to discover efficient suppliers using POM software.

Table 8 shows all RHS suppliers have a value of 1, and this makes them efficient and considered useful in the company.

Table 8. Weighting of Outputs and Inputs Variable Values in DEA

Supplier	Quality (O_1)	Delivery (O_2)	Service (O_3)	Flexibility (O_4)	Payment (O_5)	Guaranty (O_6)	Price (I_1) (Rp per unit)	Shipping costs (I_2) (Rp per order)	Lead Time (I_3) (days)	RHS
***Supplier* 1**	0,0001	0,0001	0,0001	0,0001	1,7299	0,0001	0,0001	0,0025	0,0001	1,00
***Supplier* 2**	1,5476	0,0001	0,0001	0,0001	0,0001	0,0001	0,0001	0,0033	0,0001	1,00
***Supplier* 3**	0,0001	1,869	0,0001	0,0001	0,0001	0,0001	0,0001	0,0018	0,0001	1,00

Therefore to determine suppliers that need to become partners of the company, this study employed the AHP (Analytical Hierarchy Process) to add valuation to the input variable (in DEA Method) while the calculation is continued until the assessment weight is discovered for the three suppliers. The supplier order starts with the one with the highest weight to the lowest. The results are as follows.

Table 9. AHP Weighting Results

Supplier	Weight
Supplier A	0,404
Supplier B	0,439
Supplier C	0,157

Table 9, shows that supplier B has the height weight, followed by A, and C. Therefore, supplier B was selected and utilized.

5. CONCLUSION

In conclusion, the three suppliers have the same efficiency value, therefore, they are considered partners of the company. However, by weighing all the input and output variables, supplier B was chosen by the company over others.

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