Performance evaluation of yarn raw materials supplier using fuzzy data envelopment analysis approach (case study Batik Fabric Company in Sleman)

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Abstract. Evaluating supplier performance by measuring supplier performance is an important thing by the company to optimize costs and time. This study aims to evaluate supplier performance and determine the best supplier based on predetermined criteria. This research was conducted on Batic Fabric company by taking research object suppliers of raw material for 40 CD and 50 CM yarn. This study used 4 criteria and 3 month period data. Evaluation of supplier performance using the Fuzzy Data Envelopment Analysis (DEA) approach, the Fuzzy method is used to carry out linguistic assessments, while for the assessment efficiency is used by the DEA method. The result analysis was concluded that the efficient suppliers for 40 CD yarns were suppliers PTX1, PMT1 and AG1. PMT1 is the best supplier which has the highest super efficiency value of 10.01565 while the 2nd rank is occupied by the PTX1 supplier with a super efficiency value of 1.633666 and the third rank is AG1 supplier with a super efficiency value of 1.488659 and other suppliers are inefficient: PMT1, SC1, PDT1 and AR1. For 50 CM yarn, the best supplier is PTX2 which has an efficiency value of 1, while other suppliers are inefficient: PMT2, DLT2, and DLR2.

1. Introduction

Batik fabric company is a company that moves set a policy of quality in terms of textile firm as orientation in the business. The quality policy is "Customer Satisfaction Our Pride". From the quality policy it can be seen that customer satisfaction is one of the main objectives to be achieved by the batik factory. Customer satisfaction can be created after comparing the value performance obtained with the expected value performance. One of the performance parameters can be known from the timeliness and condition of ordered goods. The timeliness of completion, the quantity and quality of goods sent, can be determined and regulated through a good production management system. One of them is planning the procurement of raw materials. Batik Fabric company has many suppliers as suppliers of yarn raw materials. At the company there are still purchasing raw materials with low quality yarn. Many found defects in raw materials purchased such as too many nep. Defects in raw materials will result in poor quality of the finished product. In addition there is a delay in the arrival of yarn raw materials and the number of yarn quantities not in accordance with orders by the company. If this is ignored, it will hamper the production process and harm the company. Of the various types of yarn used, the 40 CD and 50 CM yarns are threads that are often used in the production process and experience changes in quality. According to Pujawan and Mahendrawathi (2010), supplier performance needs to be monitored continuously. This performance monitoring is important to be carried out as an evaluation material which can later be used to improve supplier performance or as a consideration for whether or not to look
for alternative suppliers. Therefore, to maintain the stability of supplier performance, it is necessary to conduct an evaluation of the supplier's performance of yarn raw materials in batik factories by measuring supplier performance using the Fuzzy DEA approach.

Rouyende Gh & Erol in 2010 conducted a study entitled The DEA - FUZZY ANP Department Ranking Model Applied in Iran Amirkabir University. The study uses the DEA & Fuzzy ANP method as a tool to determine the ranking of each department that is efficient and inefficient so that it can be used as an evaluation material for improvement. In (2011) Dotoli & Falagario conducted research under the title A hierarchical model for optimal supplier selection in multiple sourcing contexts. The research uses DEA, TOPSIS & Linear Programming methods as a tool to show differences in the performance of each supplier based on multiple sourcing and order quantity calculations from each supplier.

2. Literature review

2.1. Performance evaluation supplier

According to Wibowo (2010), performance is doing work and the results achieved from the work, about what is done and how to do it. Performance measurement needs to be done to find out whether during the performance implementation there are deviations from the predetermined plan, whether the performance can be done according to the specified schedule, whether the performance results have been achieved as expected. Meanwhile the evaluation according to Wirawan (2009), is the process of gathering information concerning evaluation objects and assessing evaluation objects by comparing them with evaluation standards. The result is information about the evaluation object which is then used to make decisions about the evaluation object.

Performance evaluation is carried out to provide an assessment of the work results or work achievements obtained by the organization, team or individual. Performance evaluation will provide feedback on performance goals and objectives, planning and performance implementation processes. Performance evaluation can also be carried out on the process of assessment, review, and performance measurement. On the basis of performance evaluation steps can be taken to improve performance in the future (Wibowo, 2010). Supplier is also an organization that needs to be evaluated for its performance. This is very important to maintain business cooperation between company and suppliers and also to monitor and ensure products that are supplied in accordance with the specifications set by the company.

One of the fundamental aspects of supply chain management is performance management and continuous improvement. To create an effective performance management measurement system is needed that is able to evaluate the performance of the supply chain as a whole (Pujawan and Mahendrawathi, 2010). Vendor evaluation involves the process of finding potential vendors and determining the likelihood that they will become good suppliers (Heizer & Render, 2011). Supplier performance evaluation activities are part of supplier selection. Supplier selection is a strategic activity, especially if the supplier will supply critical items or will be used in the long term (Pujawan and Mahendrawathi, 2010). Many factors need to be considered in selecting suppliers. The selection process can be very complex because a company may have a number of capabilities in all fields or abilities that are so good in only a few fields [4].

2.2. Fuzzy Association Theory

The meaning of fuzzy (obscenity) is found in qualitative meanings which have relative values for different individuals. Fuzzy set theory in further development is an appropriate tool and technique for analyzing complex systems and is a decision making process of the uncertainty of a pattern caused by a blurring of randomness. This theory is built to solve problems where the description or description of activities, observations, and decision making are subjective, vague and inaccurate. The basic concept of fuzzy is the inaccuracy in defining a meaning expressed in linguistic form (Basuki et al, 2008). This form of linguistics is the naming of a group that represents a certain condition or condition by using natural language, such as young, middle age, and old [6].

According to Tettamanzi [6] suggested that fuzzy set theory is a mathematical framework used to represent uncertainty, ambiguity, inaccuracy, lack of information, and partial truth.
Kusumadewi et al (2006), states that the reasons for the use of fuzzy logic by most people are:
1. The concept of fuzzy logic is easy to understand because it is based on natural language.
2. Fuzzy logic is very flexible.
3. Fuzzy logic has a tolerance for incorrect data.
4. Fuzzy logic is able to model nonlinear functions that are very complex.
5. Fuzzy logic can build and apply the experiences of experts directly without having to go through the training process.
6. Fuzzy logic can work with conventional control techniques.

2.3. DEA (Data Envelopment Analysis)
The DEA approach was first developed theoretically by Charnes, Cooper and Rhodes in 1978. DEA is basically a linear programming based technique used to measure the relative performance of organizational units where the existence of multiple (multiple) inputs and outputs is difficult to compare. DEA identifies the relative units that use inputs in providing certain outputs in the most optimal way and DEA uses this information to form a frontier (efficiency) frontier of the available organizational unit data. DEA uses this efficient frontier to calculate the efficiency of other organizational units that are not on the efficient frontier so that it can provide information about units that do not use inputs efficiently

In compiling develop the DEA model to evaluate supplier performance, input and output variables must be determined based on company considerations related to the objectives to be achieved (Rahman, 2012). DEA is a non-parametric approach which is basically a linear programming technique. DEA works with the identification step of the unit to be evaluated, the inputs needed and the output produced by the unit. Then form the border efficiency of the available data set and calculate the productivity value of the units that are not included in the efficiency border and identify which units do not use inputs efficiently, relative to the units with the best performance from the analyzed data set [8].

The relative efficiency values from the calculation of a DMU (Decision Making Unit) with the CRS model and output oriented are obtained from the following models:

\[
\text{Max } E_m = \frac{\sum_{j=1}^{J} v_{jm} y_{jn}}{\sum_{i=1}^{I} u_{im} x_{in}}
\]

Subject to
\[
0 \leq \frac{\sum_{j=1}^{J} v_{jm} y_{jn}}{\sum_{i=1}^{I} u_{im} x_{in}} \leq 1; \quad n = 1, 2, K, N
\]
\[
v_{jm}, u_{im} \geq 0; \quad i = 1, 2, 3, K, I; \quad j = 1, 2, K, J
\]

Symbol:
- \( E_m \): efficiency of m DMU
- \( y_{jm} \): number of output variables from m DMU
- \( v_{jm} \): the weight of the output
- \( x_{im} \): number of input variables from m DMU
- \( u_{im} \): the weight of the input
- \( y_{jn} \) dan \( x_{in} \): the number of \( j \) output and \( i \) input dari n DMU, \( n = 1, 2, 3, ..., N \)

source: Ramanathan (2003, page 40).

The above formula cannot be solved using a linear program, the above formula can be changed to a linear program as follows:

\[
\text{Max } z = \sum_{j=1}^{J} v_{jm} y_{jn}
\]

Subject to
\[
\sum_{i=1}^{I} u_{im} x_{im} = 1
\]
\[
\sum_{j=1}^{J} v_{jm} y_{jn} - \sum_{i=1}^{I} u_{im} x_{in} \leq 0; \quad n=1,2, K, N
\]
3. Materials and methods

The study focused on suppliers of 40 CD yarn for 6 suppliers and 50 CM yarn for 4 suppliers. Linguistic evaluation was carried out by the Head of the PPIC/GF (grain finishing) Section of 1 person, the Head of the Laboratory for testing thread 1 person and 1 person Head of Weaving Unit. The variables criteria used in this study are as follows:

1. Quality: Regarding the ability of suppliers to fulfil quality according to standards set by the company.
2. Price: Corresponds to the price level of yarn raw material offered by the supplier and has been approved by the company.
3. Delivery: Related to the ability to meet the delivery time of raw materials from suppliers to the company.
4. Order fulfilment: Related to the ability of suppliers to fulfil the quantity of yarn raw materials based on orders from company.

These criteria were obtained based on interviews with the company and also based on research by Li et al. (1997).

The research method that is used as follows:

1. Define the problem.
2. Define the criteria of variable by brainstorming and interview with Head of PPIC.
3. Collect the data by questionnaire.
4. The results of the questionnaire were processed with fuzzy, so we got the weight of each criterion each supplier.
5. Meanwhile the DEA data is prepared by determining the DMU input and output. The input and output variables used are as follows: price as input and Quality, Delivery, Order fulfilment as output.
6. Supplier evaluation also involves historical data over a specified period and uses price, quality, delivery and order fulfilment criteria. Furthermore, the data is aggregated with criteria weights. Supplier weight values are based on criteria that have been obtained, then determine the optimization model for supplier assessment.
7. Then processed by the DEA method using Lindo software which is a linear programming technique that calculates the output ratio of input from each production unit (DMU) whose results are called relative efficiency scores. The efficiency value indicates which supplier is the best.
8. The results obtained are the value of the efficiency of each supplier and then an analysis of these results.

3.1. Fuzzy processing

Linguistic variables are used to get judgment by decision makers. The implementation of triangular fuzzy number membership functions can classify the blurring that occurs in linguistic variables. The steps in the fuzzy method are as follows:

1. Determine the fuzzy number membership function of each decision maker by using a triangular fuzzy number.

| No. | Variable Linguistik | Triangular Fuzzy Number Membership \( (l, m, u) \) |
|-----|---------------------|-----------------------------------------------|
| 1.  | VL = Very Low       | \( (0, 0.1, 0.3) \)                           |
| 2.  | L = Low             | \( (0.1, 0.3, 0.5) \)                         |
| 3.  | M = Medium          | \( (0.3, 0.5, 0.7) \)                         |
| 4.  | H = High            | \( (0.5, 0.7, 0.9) \)                         |
| 5.  | VH = Very High      | \( (0.7, 0.9, 1) \)                           |

The membership function of the triangular fuzzy numb set on the weight variable above can be represented in the following figure:
2. Tabulate the results of the assessment given in the first step to get an average value of each criterion. Because there are more than one decision makers, it is necessary to do an aggregate calculation, an aggregate calculation is performed using the geometric average approach. This is used to find out one decision value from several questionnaires with the following formula (Kang, et al. 2010):

$$r_{ij} = (a_{i1} x a_{i2} x \ldots a_{ik})^{1/k}$$  \hspace{1cm} (3)

3. Calculate the single value of the results of the second step using the defuzzification of the center of gravity method with the following formula (Kang, et al. 2010):

$$F_{ij} = \left[ \frac{(u_{ij} - l_{ij}) + (m_{ij} - l_{ij})}{3} \right] + l_{ij} = l_{ij} + \frac{m_{ij} + u_{ij}}{3}$$  \hspace{1cm} (4)

4. After calculating the defuzzification for each criterion, the next step is to normalize using the following formula:

$$\text{Weight} = \frac{\text{score each supplier}}{\text{total score all supplier}}$$  \hspace{1cm} (5)

The following results are fuzzy processing:

![Figure 2. Weight criteria of Yarn Supplier 40 CD](image)
3.2. Recapitulation of weight

Data obtained from the company for 3 months in the form of a percentage can be seen in tables 2 and 3 below:

| Supplier | Price | Quality | Delivery | Order fulfillment |
|----------|-------|---------|----------|--------------------|
| PTX1     | 21,6716 | 13,9860 | 52       | 43                 |
| PMT1     | 5,1799  | 100     | 0        | 100                |
| SC1      | 38,4292 | 0       | 16       | 51,1173            |
| AG1      | 29,8194 | 24,4624 | 32       | 100                |
| PDT1     | 4,8999  | 100     | 0        | 100                |
| AR1      | 5,1099  | 0       | 0        | 50                 |

These four criteria are classified into input and output. The price is as input and the output are quality, delivery and order fulfillment.

3.3. DEA processing

Measurement of supplier efficiency is done by using the DEA method, which is a linear programming technique that calculates the ratio of output to input of each production unit (Decision Making Unit, DMU) whose results are called relative efficiency scores (Cooper, et al. 2002). In this study to measure supplier efficiency using the CRS (Constant Return to Scale) model and output oriented with the formula (2).

The DEA mathematical model of a unit can be formulated into a fractional linear program by making the input and output weights of the units concerned as decision variables (Palit et al, 2008).

The results of the fuzzy assessment are supplier weights based on criteria, then aggregated with historical data that has been calculated as a percentage and the following are the results:
Table 4. Data input and output for each supplier yarn 40 CD

| Supplier | DMU | X1   | Y1   | Y2   | Y3   |
|----------|-----|------|------|------|------|
| PTX1     | 1   | 3,2199 | 2,2000 | 11,0163 | 7,7411 |
| PMT1     | 2   | 0,9222 | 22,5973 | 0 | 15,0232 |
| SC1      | 3   | 6,8420 | 0 | 3,3896 | 9,2024 |
| AG1      | 4   | 4,7308 | 2,2562 | 6,7433 | 17,9069 |
| PDT1     | 5   | 0,7774 | 6,3976 | 0 | 16,0416 |
| AR1      | 6   | 0,9098 | 0 | 0 | 7,5116 |

Table 5. Data input and output for each supplier yarn 50 CM

| Supplier | DMU | X1   | Y1   | Y2   | Y3   |
|----------|-----|------|------|------|------|
| PMT2     | 1   | 7,6359 | 0 | 2,4624 | 27,2553 |
| PTX2     | 2   | 9,7178 | 0 | 5,9995 | 16,8074 |
| DLT2     | 3   | 6,2954 | 0 | 0 | 17,0585 |
| DLR2     | 4   | 2,0729 | 0 | 0 | 22,7447 |

Remarks:
X1 = value of input that is the purchase price of each supplier
Y1 = value of output which is the level of yarn quality of each supplier
Y2 = value of output which is the delivery time of each supplier
Y3 = value of output which is the level of order fulfillment from each supplier

The next stage after the data is aggregated, then relative efficiency is measured, but the optimization modeling is based on equation (2) first. DEA processing is done by inserting the optimization model that has been modeled before into the LINDO software and then completing it so that the efficiency values of each DMU will be obtained.

3.4. Relative Efficiency Analysis

Based on the results of DEA processing with LINDO software, the relative efficiency values of each DMU (supplier) are obtained. Here are the results of the calculation:

Table 6. Efficient and inefficient DMU for 40 CD yarns

| Supplier | DMU | Efficient | Inefficient |
|----------|-----|-----------|-------------|
| PTX1     | 1   | 1         |             |
| PMT1     | 2   | 1         |             |
| SC1      | 3   | 0.5139025 |             |
| AG1      | 4   | 1         |             |
| PDT1     | 5   | 0.9298730 |             |
| AR1      | 6   | 0.4194807 |             |

Table 7. Efficient and inefficient DMU for 50 CM yarns

| Supplier | DMU | Efficient | Inefficient |
|----------|-----|-----------|-------------|
| PMT2     | 1   | 0.5170738 |             |
| PTX2     | 2   | 1         |             |
| DLT2     | 3   | 0.6258783 |             |
| DLR2     | 4   | 0.8345056 |             |

From the table, it can be seen that DMU 1 has an efficiency value of 1, this means that the performance of DMU 1 (supplier PTX1) for 40 CD yarn is quite efficient while DMU-DMU which has an efficiency value of less than 1 is categorized as inefficient, as well as for the supplier yarn
performance results 50 CM. Suppliers whose efficiency value is less than 1 are suppliers in their operational activities that have not been efficient in utilizing all of their potential capabilities to be able to produce maximum output. Suppliers who have low efficiency values, namely SC1 and AR1 for 40 CD yarn suppliers and DLT2 for 50 CM yarn suppliers, the cause of SC1 suppliers is inefficient, because in that period it is the rainy season and this causes flooding in various cities, one of which is in Jakarta and SC1 suppliers are located in Jakarta so that SC1 cannot operate optimally and as one of its impacts, it is unable to fulfill orders from Batik Fabric company. Besides the factors that influence is the occurrence of damage to transportation on the road so that slowing the delivery (delivery). Thus SC1 performance is less than the maximum. As for the AR1 supplier the inefficiency according to the planner is that there is too much wax in the thread so there is a need for prior communication before making a decision and as a result requires more time for negotiation and waits for a better yarn production than AR1. This will affect the performance of AR1 suppliers in partnering business with Batik Fabric factories. If this waxy substance is left alone it will disrupt the weaving production process in the batik fabric company, the disturbance is in the form of excessive thread adhesiveness. While the DLT2 supplier is inefficient according to the planner, which is the presence of too much honey cotton. Too much honey will cause disruption to the warping process, namely the thread will be hot and break easily so that it can hamper the production process in the Batik Fabric company. Therefore communication needs to be done first before making a decision and as a result requires more time for negotiation and waiting for a good yarn for yarn production results better than DLT2.

3.5. Super Efficiency Analysis

Based on the calculation of DEA with the CRS (Constant Return to Scale) model and output oriented, we get 3 suppliers of 40 CD threads with one efficiency value (table 4.5). To find out which of the three suppliers is the best, it is necessary to rank it using super efficiency calculations.

The basic concept of super efficiency is to allow the observed DMU efficiency to be greater than one or 100%. This is obtained by removing the associated constraints from the series of constraints or constraints p, so that there is no efficiency limit smaller than 1 for the p-DMU. Super efficiency only affects units (DMU) that are considered to be as efficient as the boundaries removed, which do not bind inefficient units because their efficiency is less than 1 or 100% [10].

The concept of super efficiency concept is almost the same as DEA CRS formulation, which differs only in output-input constraints, where in super efficiency removes the value of output-input constraints for the p-supplier or supplier being evaluated. The purpose of removing this obstacle is that the efficiency value of the supplier being evaluated can be greater than 1 or 100% with the aim of ranking suppliers that are already efficient [10].

Based on the results of calculations with LINDO software, we get the value of super efficiency and ranking for each supplier as shown in table 8 below:

| DMU  | Supplier | Value of super efficient | Rank |
|------|----------|--------------------------|------|
| DMU 1| PTX1     | 1,633666                 | 2    |
| DMU 2| PMT1     | 10,01565                 | 1    |
| DMU 4| AG1      | 1,488659                 | 3    |

From table 8 it can be seen that for 40 CD threads, DMU 2 has the highest super efficiency value of 10,01565, this means that the performance of DMU 2 (supplier PMT1) is the best supplier by obtaining rank 1 while ranking 2nd is occupied by DMU 1 is the supplier of PTX1 with a super efficiency value of 1.633666 and the third rank is DMU 4 (AG1) with a super efficiency value of 1.488659.

Batik Fabric company should make the process of purchasing raw materials to efficient suppliers, in this case PMT1 for 40 CD yarn suppliers, and PTX2 for 50 CM yarn suppliers, because the supplier has an efficiency value of 1 based on DEA calculations with LINDO software.
Conclusion
1. The result is supplier performance level based on performance evaluation with Fuzzy DEA for 40 CD threads, namely suppliers PTX1, PMT1 and AG1, including efficient. Of the three suppliers, PMT1 is the best supplier because it has the highest super efficiency value of 10.01565 while the 2nd rank is occupied by the PTX1 supplier with a super efficiency value of 1.633666 and the third rank is AG1 supplier with a super efficiency value of 1.488659. While other suppliers are inefficient namely SC1, PDT1 and AR1 with efficiency values respectively 0.5139025, 0.9298730 and 0.4194807. For 50 CM yarn, the best supplier is PTX2 because it has an efficiency value of 1, while other suppliers are inefficient, namely PMT2, DLT2, and DLR2 with efficiency values respectively 0.5170738, 0.6258783 and 0.8345056. Inefficient suppliers occur because they are unable to fulfill the orders of Batik Fabric company and delivery delays. For suppliers that fall into the efficient category it can be interpreted that is able to provide good performance for Batik Fabric company.

2. The factors that affect the performance of yarn raw material suppliers, namely quality, price, delivery, and order fulfillment. By evaluating the performance of supplier the company can obtain useful information for company management feedback in monitoring performance, diagnosing problems and identifying company successes.

3. The performance of suppliers of yarn raw materials can be known by measuring the valuation using the Fuzzy Data Envelopment Analysis approach where the Fuzzy method is used to carry out linguistic assessments so that the weighting value of each supplier is obtained, while for the supplier efficiency assessment the Data Envelopment Analysis (DEA) method is used.

4. As for discussion, the results of supplier performance evaluation based on research over a period of 3 months can be used as recommendations, namely maintaining existing suppliers, looking for alternative other suppliers or combining between suppliers. And suggestions for further research is to evaluate performance using Fuzzy DEA will be more perfect if it is equipped with other methods as a comparison and use of the Decision Support System (DSS) to design the application.

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