Supply Chain Performance Analysis With Data Envelopment Analysis in TBBM PT. Pertamina Boyolali

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Abstract. PT. PERTAMINA TBBM Boyolali is a supplier of fuel oil in the form of premium, pertamax and diesel. The company should distribute fuel products using tank cars with operating areas covering Boyolali, Surakarta, Karanganyar, Sukoharjo, Sragen, Klaten, Wonogiri, Pacitan, Magetan, Ungaran, Semarang, Salatiga, Purwodadi, and Blora. An efficient supply chain is needed to provide the right products and services, with the specifications needed, in the right place and to the right customers. This article aims to find out and analyze the efficiency that occurs at operational TBBM Pertamina Boyolali and to find out the variables that most influence supply chain performance to be analyzed and improved so that improvements in supply chain performance can be more focus and optimal. The Decision-Making Units (DMUs) stated in this article are the period of supply chain activities from January 2018 to November 2018 at TBBM Pertamina Boyolali, the number of DMU is 11 DMUs. Supply Chain Operation Reference (SCOR) method with responsiveness, flexibility, and reliability attributes is used to measure Supply chain performance. To analyze supply chains efficiency, this article applies input-oriented DEA CCR (Charnes, Cooper, and Rhodes) model which considers linear relationships in its input and output. Data Envelopment Analysis (DEA) is a strong tool for measuring the efficiency of the DMUs and does not need to normalize indicator values that have different dimensions. The software used for processing data in this article is Banxia Frontier Analyst 4.2. This article provides suggestions for improving cash-to-cash cycle time, lead time, and flexibility for more efficient fuel distribution.

1. Introduction
At present, the supply chain has become a very important problem in companies when effective supply chain management leads to high-performance supply chains. The supply chain has involved many companies working together in such a way that the competition created is not between companies but between supply chains. The complexity which tends to develop and the increasing involvement of various stakeholders in the supply chain has shown the need for performance measurement and re-engineering of the business processes that have been traversed [1]. In the distribution of petroleum, supply chain costs up to 40% of the total cost of refining and distribution, so that effective management and optimization of the chain is very important in improving the performance of logistics and SCM.

TBBM Boyolali is one part of the Marketing Operation Region IV - PT Pertamina, which in its operation has used the Terminal Automation System (TAS). TBBM PT. Pertamina Boyolali is located
The Boyolali BBM Terminal receives fuel supplies from the Lomanis Transit Terminal through multi-product pipes using the CY2 pipeline. The length of the CY2 pipe is 246 km with an average flow rate of 300 kiloliter/hour and the total volume of the pipe contents is 18,098 kiloliter. TBBM PT. Pertamina Boyolali receives fuel products (Premium, Pertamax and Solar) from the Lomanis Transit Terminal through pipelines, stores in storage tanks, and distributes using tank cars with operating areas including Boyolali, Surakarta, Karanganyar, Sukoharjo, Sragen, Klaten, Wonogiri, Ngawi, Pacitan, Magetan, Ungaran, Semarang, Salatiga, Purwodadi, Blora.

Data Envelopment Analysis (DEA) has proven to be a strong tool in measuring the efficiency of Decision Making Units (DMUs). Also, this method is not necessary to normalize indicator values with different dimensions. The term DMU is referred to every production unit with certain inputs and outputs. In the literature on the evaluation of operational performance, certain DEA models are widely applied by many researchers. Tajbakhsh & Hassini (2015) [1] and Fathi & Saen (2018) [2] evaluated sustainability in the distributive chain of transportation companies. Huang, (2018) [3] assessing the performance of tourism supply chains with N-DEA. Boudaghi & Farzipoor Saen (2018) [4] carried out the development of the DEA model to predict the removal of suppliers in the supply chain. Goodarzi & Saen (2018) [5] analyzed the phenomenon of the bullwhip effect in the supply chain using DEA. Saputri, Sutopo, Hisjam & Ma’aram (2019) [6] analyzed sustainable agri-food supply chain performance measurement model for GMO and Non-GMO.

In this study, we use the input-oriented DEA-CCR model. This model is a DEA model that was developed by Charnes, Cooper, & Rhodes in 1978 [7]. This model is also called the Constant Return to Scale (CRS) model, which considers linear relationships in the input and output. Every increase in the input will result in a proportional and constant increase in output. This can mean that efficiency will not change on a scale regardless of the unit operating. Input-oriented measurement is the identification of inefficiencies through the possibility to reduce inputs without changing the output value [8]. This article aims to find out and analyze the efficiency that occurs at operational TBBM Pertamina Boyolali and to find out the variables that most influence supply chain performance to be analyzed and improved so that improvements in supply chain performance can be more focus and optimal.

Based on the literature review by Najmi, Gholamian, & Makui (2013) [9], the development of performance analysis methods are as follows.

| Number | Method | Reference | Method | Reference |
|--------|--------|-----------|--------|-----------|
| 1      | Simulation Delphi | Persson & Olhager, 2002 [10] | 13  | DEA | Wong, 2009) [22] |
| 2      | Delphi | Bottani & Bigliardi, 2010 [11] | 14  |   | Xu, Li, & Wu, 2009 [23] |
| 3      | AHP | Chan, 2003 [12] | 15  |   | Peng Wong & Yew Wong, 2008 [24] |
| 4      |   | Yang, 2009 [13] | 16  |   | Peng Wong & Yew Wong, 2007 [25] |
| 5      |   | Wadhwa, Varma, & Deshmukh, 2008 [14] | 17  |   | F. Yang, Wu, Liang, & Bi, 2011 [26] |
| 6      |   | Bhagwat & Sharma, 2009 [15] | 18  |   | Hamid, Hakim, Lin, & Choy Chong, 2009 [27] |
| 7      |   | Drzymalski, Odrey, & Wilson, 2010 [16] | 19  |   | Parkan & Wang, 2007 [28] |
| 8      |   | Bhagwat & Sharma, 2007 [17] | 20  | Hybrid | Berrah & Clivillé, 2007 [29] |
| 9      |   | Askariazad & Wanous, 2009 [18] | 21  |   | Jia & Ierapetritou, 2003 [30] |
| 10     |   | Bhagwat, Chan, & Kumar Sharma, 2008 [19] |   |   |   |
Based on the State of the Art, the DEA method is used by 8 studies from 24 studies. Research with the DEA method is quite popular for performance analysis.

2. Quantitative Approach

Supply Chain Operation Reference (SCOR) method with responsiveness, flexibility, and reliability attributes is used to measure Supply chain performance. To analyze supply chains efficiency, this article applies input-oriented DEA CCR (Charnes, Cooper, and Rhodes) model which considers linear relationships in its input and output. Data Envelopment Analysis (DEA) is a strong tool for measuring the efficiency of the DMUs and does not need to normalize indicator values that have different dimensions. The software used for processing data in this article is Banxia Frontier Analyst 4.2. The Distribution Channel of PT. TBBM Boyolali is shown in Figure 1.

![Distribution Channel of PT. TBBM Boyolali](image)

The Decision-Making Units (DMUs) stated in this article are the period of supply chain activities from January 2018 to November 2018 at TBBM Pertamina Boyolali, the number of DMU is 11 DMUs. The classifications of DMUs are shown in Table 2.

**Table 2. The classifications of DMUs in 2018**

| Month    | DMU  |
|----------|------|
| January  | DMU 1|
| February | DMU 2|
| March    | DMU 3|
| April    | DMU 4|
| May      | DMU 5|
| June     | DMU 6|
| July     | DMU 7|
| August   | DMU 8|
| September| DMU 9|
| October  | DMU 10|
| November | DMU 11|
Variables used based on the method of Supply Chain Operation Reference (SCOR) are responsiveness, flexibility, reliability, and financial measures. Responsiveness is seen from the cash-to-cash cycle time and lead time (order fulfillment cycle). Cash-to-cash cycle time is used to measure the time starting from the incoming order until the product reaches the consumer. Cash-to-cash cycle time is calculated based on days sales outstanding (DSO) added days of inventory (DOI) then minus days payable outstanding (DPO). Increasing DPO, reducing DSO and DOI can minimize the value of the cash-to-cash cycle time. DSO size shows existing collectible receivables. The longer the collectible receivables are recorded, then the company's financial flows will be disrupted. DOI shows inventory turnover speed. The DPO shows the number of hours the debt is paid to the supplier. Lead time is the period required from the time of order until the ordered item has been received.

Flexibility is the tenacity of the supply chain and the ability to adapt to changes in market demand to maintain supply chain competitive advantage. Flexibility is defined as the ability to respond to consumer requests and overtake competitors. Flexibility is one of the determining factors in the market competition [33]. The input and output variables used in this article are shown in Table 3.

### Table 3. Input and Output Variables

| No | Variable          | Sub-criteria Variable          | Unit | Type of Criteria | Explanation                                                                 |
|----|-------------------|--------------------------------|------|------------------|-----------------------------------------------------------------------------|
| 1  | Responsiveness    | Cash-to-cash cycle time        | Hours| Input            | The time needed from the fuel is bought by TBBM until it is purchased by the customer |
|    |                   | Lead time                      | Hours| Input            | The time needed by suppliers to fulfill orders                               |
| 2  | Flexibility       | Flexibility                    | Hours| Input            | The company's ability to respond to changes in company orders                |
| 3  | Reliability       | Compliance with standards      | %    | Output           | Percentage of suitability of the product entering the gas station          |
|    |                   | Order fulfillment              | %    | Output           | Persentase pemenuhan pesanan konsumen                                      |
|    |                   | Delivery performance           | %    | Output           | Percentage of timeliness in order fulfillment                               |

Calculations performed to obtain the output variable are as follows.

a. Conformance to standard (%)

\[
\frac{\sum \text{receipt}}{\text{Number of products rejected}} \times 100\% \quad \text{Equation (1)}
\]

b. Order fulfillment (%)

\[
\frac{\sum \text{order completion}}{\sum \text{order receipt}} \times 100\% \quad \text{Equation (2)}
\]

c. Delivery performance (%)

\[
100\% - \left( \frac{\text{Receipt date} - \text{date of appointment}}{\text{Lead Time}} \right) \times 100\% \quad \text{Equation (3)}
\]

Calculation of Efficiency Value was done by Banxia Frontier Analyst 4.2 software. The following equation with the input-oriented DEA-CCR model.

a. Objective function

\[
\text{MAX} h_n \sum_{i=1}^{m} \mu_i y_i \quad \text{Equation (4)}
\]

b. Constrain
\[ \sum_{i=1}^{m} v_{ij} = 1 \]  
\[ \sum_{i=1}^{m} u_r y_{ij} - \sum_{i=1}^{m} v_{ij} \leq 0, \ j = 1, \ldots, n \]  
\[ u_r, v_i > 0, r = 1, \ldots, t, i = 1, \ldots, m \]

\( h_n = \) DMU relative efficiency  
\( t = \) number of outputs  
\( m = \) number of inputs  
\( u_r = \) weight of output \( r \)  
\( v_i = \) weight of input \( i \)  
\( y_{rj} = \) value of the fourth output from DMU to \( j \)  
\( x_{ij} = \) the first input value from the DMU to \( j \)

3. Result and Discussion

Data input and output chain variables are shown in table 3. Data analysis was carried out with the help of Banxia Frontier Analyst 4.2 software. In the table 4, 5, and 6, there are 3 conditions with 3 different colors: green for efficient conditions with a value of 100%, yellow for Ammber conditions with a value of 95% -99.99% (with improvement potential) and red for conditions under 95% [34]. Table 4 shows data of input variable and output variable of 1st Supply Chain Alternative

| Table 4. Data Input Variable And Output Variable of 1st Supply Chain Alternative |
|-----------------------------------------------|
| Month | Input | Output |
| Cash-to-cash Cycle Time | Lead Time | Flexibility | Compliance with standards | Order fulfillment | Delivery performance |
| Hour | Hour | Hour | % | % | % |
| 1 | 83 | 24 | 11 | 96 | 100 | 93 |
| 2 | 96 | 22 | 9 | 100 | 100 | 90 |
| 3 | 92 | 20 | 9 | 98 | 100 | 88 |
| 4 | 87 | 19 | 12 | 96 | 100 | 90 |
| 5 | 54 | 32 | 18 | 100 | 97 | 95 |
| 6 | 81 | 22 | 11 | 99 | 100 | 98 |
| 7 | 90 | 24 | 12 | 100 | 95 | 95 |
| 8 | 93 | 20 | 10 | 100 | 100 | 100 |
| 9 | 93 | 19 | 11 | 99 | 100 | 85 |
| 10 | 92 | 20 | 14 | 100 | 100 | 98 |
| 11 | 84 | 20 | 11 | 98 | 99 | 88 |

Table 5 shows data of input variable and output variable of 2nd Supply Chain Alternative

| Table 5. Data Variable Input Dan Variable Output of 2nd Supply Chain Alternative |
|-----------------------------------------------|
| Month | Input | Output |
| Cash-to-cash Cycle Time | Lead Time | Flexibility | Compliance with standards | Order fulfillment | Delivery performance |
| Hour | Hour | Hour | % | % | % |
| 1 | 90 | 17 | 11 | 96% | 98% | 97% |
| 2 | 90 | 18 | 9 | 99% | 95% | 91% |
| 3 | 92 | 15 | 8 | 98% | 100% | 95% |
| 4 | 90 | 15 | 8 | 100% | 97% | 100% |
| 5 | 85 | 18 | 8 | 96% | 95% | 100% |
| 6 | 85 | 19 | 9 | 97% | 98% | 100% |
| 7 | 90 | 20 | 7 | 199% | 100% | 96% |
In the table 4, 5, and 6, there are 3 conditions with 3 different colors. Green for efficient conditions with a value of 100%, yellow for Amber conditions with a value of 95% -99.99% (with improvement potential) and red for conditions under 95% [34]. The data on the efficiency value of each DMU in the 1st Alternative has the lowest efficiency value in July 2018 of 88.1%. From the overall data obtained the efficient value of green at 9 DMU is in January, February, March, April, May, June, August, September, November. Amber conditions in October, as well as Red's condition in July. The lowest efficiency value was obtained in November at 94.20% for the 2nd Alternative. In the table, there were 8 green DMU conditions, namely in March, April, May, July, June, August, September, and October. Amber's condition in January, and February and Red's condition in November. The average value in alternative 1 obtained at 98.74% and in alternative 2 at 98.82%. Hence based on this condition it is still possible to make improvements based on a potential improvement to increase the efficiency value to 100%.
Overall, the supply chain performance in alternatives 1 and 2 is quite good with the results of calculations on amber conditions. To get the optimal value in alternatives 1 and 2, it is necessary to improve input performance by decreasing the actual value of the existing input variable. The repairs are carried out in several ways.

1. **Cash-to-cash cycle time**
   Improvement In 1st alternative, improvements in the cash-to-cash cycle time can be done by reducing the value of the input variable by 16.32% so that the actual value can reduce from 86 hours to 72 hours. In 2nd alternative, there is a reduction of 32.81% at the actual value so that the actual time of 87 hours is reduced to 58 hours. The action that can be taken is by updating the agreement or payment method between Pertamina and SPBU to facilitate payment at the end of the deadline or can use the credit payment system. This will greatly influence the increase in the value of efficiency if an improvement in the cash-to-cash cycle time factor is made.

2. **Lead time improvement**
   Improvement of lead time is done by reducing the input value by 25.21% in 1st alternative and by 32.81% in 2nd alternative. So the actual value in 1st alternative can be reduced from 22 hours to 16 hours and in 2nd alternative from 17 hours to 12 hours. Steps that can be taken to reduce lead time can be done by setting a better delivery schedule with the order forecasting process before entering the order and reviewing the shipping hours where the previous delivery is served from 12 pm to 9 pm.

3. **Flexibility Improvement**
   Improvement of time flexibility is done by reducing the input value by 45.18% in 1st alternative and by 32.81% on 2nd alternative. So that the actual value in 1st alternative can be reduced from 11 hours to 6 hours and in 2nd alternative from 9 hours to 7 hours. Steps taken to support this change can be done by preparing a truck that specifically serves orders that require fast supply needs and a fast ordering process with a payment delay system.

An efficiency value of 100% must be achieved for each output variable in the supply chain. This value can be achieved by improving the actual value. Improvements are made by reducing input values with the results of the input variable in the 1st alternative are cash-to-cash cycle time of 72 hours, lead time of 16 hours and flexibility of 6 hours and for input variables in the 2nd alternative are cash-to-cash 59 hours cycle time, 12 hours of lead time, and 7 hours of flexibility. The input variables that most
influence the supply chain efficiency value on the 1st alternative and 2nd alternative are lead time and flexibility. So that lead time and flexibility are the most influential factors to be improved in this case.

4. Conclusion
PT. PERTAMINA TBBM Boyolali should distribute fuel products using tank cars with operating areas covering Boyolali, Surakarta, Karanganyar, Sukoharjo, Sragen, Klaten, Wonogiri, Ngawi, Pacitan, Magetan, Ungaran, Semarang, Salatiga, Purwodadi, and Blora. The Decision-Making Units (DMUs) stated in this article are the period of supply chain activities from January 2018 to November 2018 at TBBM Pertamina Boyolali, the number of DMU is 11 DMUs. This article provides suggestions for improving cash-to-cash cycle time, lead time, and flexibility for more efficient fuel distribution. Improvements using the DEA-CCR model in the case of Pertamina's Fuel Distribution can be used to increase efficiency by changing input values for 3 variables, namely cash-to-cash cycle time, lead time, and flexibility. This article has certain limitation that should be overcome in order to provide in deep analysis on the performance measurement analysis. For further research will complete the research with Balance Score Card for more balance set of performance measures.

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