Data Envelopment Analysis (DEA) Model in Operation Management

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Abstract. Quality management is an effective system in operation management to develops, maintains, and improves quality from groups of companies that allow marketing, production, and service at the most economical level as well as ensuring customer satisfaction. Many companies are practicing quality management to improve their business performance. One of performance measurement is through measurement of efficiency. One of the tools can be used to assess efficiency of companies performance is Data Envelopment Analysis (DEA). The aim of this paper is using Data Envelopment Analysis (DEA) model to assess efficiency of quality management. In this paper will be explained CCR, BCC, and SBM models to assess efficiency of quality management.

Keywords: Data Envelopment Analysis, Quality Management, performance measurement

1. Introduction

Operation management is a management system maximally of production factors in transformation process to be various products and services. Operation management is an effort to convert inputs into outputs by using physical resources so give benefits customers to meet effectiveness, the aim, compatibility and efficiency of companies [11].

The aim of operation management is to producing products or services with right quality and quantity at the time and right production cost so can be result maximum profit. Quality control is one of the important factors in operation management. Quality control is the way that used to improve and result level of products and services quality which are desired. This is systematic control from many factors that influence products or services quality.

Various the quality measurement include performance, features, reliability, durability, commitment to due date, etc. Now, customers demand products and services with greater durability and reliability at the most economical price. This forces manufacturer to follow procedure of right quality start from design until delivery and installation of product. So, the aim of competitive industries are producing products or services at the economical price and can used customers satisfaction. This can be achieved through total quality management [11].

Total quality management is effective system in operation management to develops, maintains, and improves quality of groups in company so allows marketing, production, and services at the most economical level and ensure customers satisfaction. Many companies that practicing quality management to improve business performance and still competitive in industries.

Uyar [14] show that financial and nonfinancial measures must be used in a balanced way to evaluate quality performance of companies. Therefore need a the tool can be used to assess
quality performance of companies based on financial and nonfinancial measurements. One of the companies performance measurement level is efficiency assessment. There are several methods can be used to assess efficiency, such as: Stochastic Frontier Analysis (SFA) and Data Envelopment Analysis (DEA).

SFA method were parametric approach that allow to give greater specification, especially in the case of panel data. SFA can be used to statistical test and construction confidence intervals. However, while a statistical stochastic approach allow result frontier for all data and this is not consistent to tecnological development. Therefore, the choice between different approaches must be based on trade-off concerning the purpose of the study, type of data, technology characteristics [12].

DEA method were nonparametric approach to asses performance set of entities which are called Decision Making Units (DMUs) that change inputs into outputs. Since DEA the first time introduced until current formulation, the researchers various fields had admitted that DEA method excellent and easy used to modeling operational process in assess performance. This had been accompanied by other developments. The examples, Zhu [15] presented a spreadsheet DEA model can be used to assess and became a benchmark of performance. Pournader [13] developed DEA model to outsourcing performance quality assessment in services supply chain. Use of this model in manufacturing requires a review to inputs, outputs, and intermediate products such as production and purchase of facilities, market speed, security, etc.

DEA can be used to assess efficiency level with existence of several inputs and outputs entities. Efficiency measurement quality performance of companies very needed to compare performance of companies with their competitors, and developed their business based on performance improvement plan. Therefore, this study is focused on capability Data Envelopment Analysis to assess efficiency of quality management.

2. Measurement Efficiency of Quality

Critical Factors in total quality management that found in literature vary from several writer, however there were common factors [5], such as:

- customer based approach
- management leadership and commitment
- quality planning
- management based on facts
- continuous improvement
- Human resource management
- learning
- process management
- cooperation with suppliers

Performance measurement system, measuring inputs and outputs on operation include explain good or bad operation by use that system. Performance measurement important for all functional division in companies, especially operation management which directly impact on bussiness in the process efficiency include purchase acquisition and raw material inventory. Simple efficiency ratio [1], that is: \( \frac{\text{Output}}{\text{Input}} \), be measured on individual variable that is employee, machine, and room.

Two important things in quality management were improvement process management and production quality. Improvement reliability and conformity in production process can improve internal process quality. Improvement of product quality can increase market share, higher prices, and better reputation. Therefore both of these things can increase profit and operational
performance. Relationship between quality management and performance of companies, that is: quality performance, financial performance, and operational performance.

3. Data Envelopment Analysis (DEA)
Data Envelopment Analysis (DEA) was introduced by Charnes, Cooper, dan Rhodes [2]. DEA method was made as tool to evaluate performance an activity in entity units or organization. DEA was nonparametric approach which is basically a technique linear programming. The researchers on several fields quickly admitted that DEA was excellent methodology to modelling operational process.

On DEA, Companies were called as Decision Making Units (DMUs). Term Decision Making Units (DMUs) was introduced in the same way as entities, each of entities be evaluated as part of group that utilize inputs to producing outputs. The result of evaluation made in score efficiency about between 0 until 1 and represent degree of efficiency which is obtained from entities assessed. Whit the score, DEA also identified source and number of not efficient DMUs on every input and output. It also identified DMU (that placed on efficient frontier) that included actively in the appearance of these results. Assessment entities were all efficient DMUs and hence can function as benchmarking to effective improvement at future performance from DMUs be evaluated [4].

Some basic DEA models and expansion DEA models used in this paper that is: CCR model, BCC model, and Slack-Based (SBM) model.

3.1. CCR Model
CCR DEA model was the first DEA model which was introduced by Charnes, Cooper dan Rhodes (1978). Consider there are \(n\) DMUs, that are: \(DMU_1, DMU_2, DMU_3, \ldots, DMU_n\). Each \(DMU_j, (j = 1, \ldots, n)\) use \(m\) inputs \(x_{ij} (i = 1, \ldots, m)\) dan generates \(s\) outputs \(y_{rj} (r = 1, \ldots, s)\). Let the input weights \(v_i (i = 1, 2, \ldots, m)\) and the output weight \(u_r (r = 1, 2, \ldots, s)\) as variables. Let the \(DMU_j\) to be evaluated on any trial be designated as \(DMU_o (o = 1, 2, \ldots, n)\). The efficiency of each \(DMU_o\), \(e_o\), is thus found by solving the linear programming below, which is known as multiplier form in DEA [10]:

\[
e_o = \max \sum_r u_r y_{ro} \tag{1}
\]

\[
s.t \quad \sum_r u_r y_{r0} - \sum_i v_i x_{i0} \leq 0 \\
\sum_i v_i x_{i0} - 1 \\
u_r, v_i \geq 0
\]

The model is run \(n\) times in identifying the relative efficiency scores of all the DMUs. Each DMU selects a set of input weights \(v_i\) and output weights \(u_r\) that maximize its efficiency score. Generally, a DMU is efficient if it obtains the maximum score of 1, else a DMU is inefficient.

Model dikerjakan \(n\) kali untuk mengidentifikasi skor efisiensi relatif dari seluruh DMU. Setiap DMU memilih sekumpulan bobot input \(v_i\) dan bobot output \(u_r\) yang memaksimumkan skor efisiensinya. Secara umum DMU efisien jika memperoleh skor 1 jika tidak maka DMU tidak efisien. CCR model is that it assumes constant return to scale (CRS), which may not be true for some applications. To address this issue, researchers have implemented variable return to scale (VRS) into the original DEA model.
3.2. BCC Model

DEA model that implemented Variable Return to Scale (VRS) was known as model BCC, Banker, Charnes dan Cooper (1984). In BCC model, VRS is assumed and the efficient frontier is formed by the convex hull of the existing DMUs. The envelopment form of BCC [10] is

\[
\min \theta_o
\]

\[s.t \quad \sum_j \lambda_j x_{ij} - \theta_o x_{io} \leq 0\]

\[\sum_j \lambda_j y_{rj} - y_{ro} \geq 0\]

\[\sum_j \lambda_j = 1\]

\[\lambda_j \geq 0\]

Note that BCC differs from CCR in that it has the additional convexity constraint, \(\sum_j \lambda_j = 1\)

A DMU is BCC efficient if it has an optimal solution of \(\theta = 1\) \(\lambda = 1\), and \(\lambda \neq 0\).

3.3. Slack Based Model (SBM)

A variation model was proposed by name slack based model (SBM) that representing measurement efficiency [10]:

\[
\min \rho = 1 - \frac{1}{m} \sum_i s_i^- / x_{io}
\]

\[1 + \frac{1}{n} \sum_r s_r^+ / y_{ro}\]

\[s.t \quad \sum_j \lambda_j x_{ij} - x_{io} + s_i^- = 0\]

\[\sum_i \lambda_i y_{rj} - y_{io} - s_r^+ = 0\]

\[\sum_j \lambda_j = 1\]

\[\lambda_j, s_i^-, s_r^+ \geq 0\]

which \(s_i^-\) and \(s_r^+\) are slacks, \(s_i^-\) is input excesses dan \(s_r^+\) is output shortfalls. The optimum solution of SBM is 1, which can only be achieved when all the slacks equal to zero. This is consistent with CCR and BCC models.

4. Efficiency of Quality Management Using Data Envelopment Analysis (DEA) Model

Performance measurement in this paper include measuring quality, operational and financial. Then divided into specific variables like the following table:

In this study given an illustration example about quality management, data is taken from research had developed earlier by Kuah, Wong, and Behrouzi [9]. Illustration problem consist of 10 small companies as DMUs with 2 inputs and 4 outputs. The inputs and outputs data:

- Quality costs \((x_1)\);
- Employees involved in quality \((x_2)\).
Table 1. Performance Measures dan output variables

| Performance Measures          | output variables       |
|------------------------------|------------------------|
| Quality Performance Measures | Quality products (%)   |
|                              | Customer satisfaction rate (%) |
| Operational Performance Measures | On-time delivery rate (%) |
| Financial Performance        | Measures Revenue (million USD) |

Output:
- Quality products \(y_1\);
- Customer satisfaction rate \(y_2\);
- On-time delivery rate \(y_3\);
- Revenue \(y_4\).

Table 2 show inputs and outputs data from 10 DMUs. These data should be transformed into CCR, BCC, and SBM models, then determined which companies are already efficient. Linear Programming models are run by software LINDO.

Table 2. Data for illustration example

| DMU | \(X_1\) | \(X_2\) | \(Y_1\) | \(Y_2\) | \(Y_3\) | \(Y_4\) |
|-----|--------|--------|--------|--------|--------|--------|
| 1   | 18     | 39     | 98     | 92     | 91     | 17     |
| 2   | 27     | 40     | 92     | 93     | 98     | 22     |
| 3   | 30     | 50     | 95     | 92     | 81     | 33     |
| 4   | 19     | 44     | 93     | 92     | 82     | 40     |
| 5   | 31     | 35     | 95     | 96     | 97     | 37     |
| 6   | 17     | 33     | 93     | 92     | 95     | 31     |
| 7   | 23     | 47     | 91     | 93     | 81     | 32     |
| 8   | 30     | 46     | 90     | 94     | 92     | 29     |
| 9   | 17     | 38     | 95     | 99     | 96     | 16     |
| 10  | 22     | 42     | 96     | 96     | 84     | 14     |

5. Conclusion
One of methods can be used to solve efficiency in operation management by Data Envelopment Analysis (DEA). By focusing on measure quality performance, operational performance, and financial performance can be evaluated what extent system of quality management can be repaired to development business performance of companies and still competitive in industries. This paper extends the allocation resources of literature about application DEA in a reciprocal context between efficiency and effectiveness in quality management of companies. From comparison result on illustration example were done by DEA CCR, BCC, and SBM obtained the same result to DMU 4, 6, and 9. Whereas for other DMUs there were difference of results so the next research should be done improvement or review of data inputs to produce appropriate outputs, so that DMUs were efficient.
Table 3. Efficiency of 10 DMU

| DMU | $\theta^*_CCR$ | $\theta^*_BCC$ | $\rho^*_SBM$ |
|-----|--------------|--------------|--------------|
| 1   | 0.98         | 1            | 1            |
| 2   | 0.85         | 1            | 1            |
| 3   | 0.68         | 1            | 1            |
| 4   | 1            | 1            | 1            |
| 5   | 1            | 0.94         | 0.76         |
| 6   | 1            | 1            | 1            |
| 7   | 0.75         | 1            | 1            |
| 8   | 0.73         | 1            | 1            |
| 9   | 1            | 1            | 1            |
| 10  | 0.82         | 1            | 1            |

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