Erasmus University Rotterdam

MSc in Maritime Economics and Logistics

2009/2010

Measuring Relative Container Terminal Efficiency in Indonesia

By

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Acknowledgment

Although this thesis is an effort and personal commitment in order to complete the study in MEL, the process of writing this thesis cannot be separated from the help of people around me. Special thank goes to my lovely wife, Ir. Ida Wiryanti, MSi for her support during my thesis completion and during my study in the Netherland.

I also want to thank to my supervisor, Dr. Michele Acciaro, for his support and his assistance in writing the thesis. His understanding, encouraging and personal guidance have provided a good basis for the present thesis. And deepest gratitude I expressed to Professor Hercules Haralambides, a person who via his papers has driven and motivated me to join and study at MEL.

My sincere thanks are also due to all professors at MEL, Erasmus University for the helps, encouragements and good lessons during my study at MEL.

I would also like to thank my friends Arif, Budi, Bimo, Herman, Prasetyo, Dida, Iman dan Irwan for the helps and friendships in the past two years.

I would also like to express my gratitude and acknowledgement to PT. Pelindo II for sending me to study at MEL, Erasmus University and for its financial support.

During the completion of my Thesis I have collaborated with many colleagues for whom I have great regard, and I wish to extend my warmest thanks to all those who have helped me with the completion of this Thesis.

TH Andenoworih

Abstract

The main objective of the thesis is to measure efficiency of container terminals in Indonesia. The measurement has been performed by applying Data Envelopment Analysis (DEA), a non parametric approach.

According to the study on DEA application in port sector, efficiency of container terminal is influenced by port size, port geographical, privatization and better incentive of production but the case occurred in Indonesia is different. Of the 12 container terminals observed, four of them present efficient terminals. Three out of four efficient terminals are not surprising because they are located in Jakarta, managed by private and serve international ships. But one of them, Pontianak container terminal is surprising because Pontianak container terminal is a small river port, serves small ship and operated by State-owned Company.

The result is also surprising because TPS container terminal, the second biggest container terminal and managed by Dubai port, is not included as an efficient terminal. The phenomenon is theoretically difficult to explain. The only explanation may be the existence of any strong correlation between efficiency of container terminal and precision of strategic port planning.

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Chapter 1 Introduction

1.1 Background

Container terminal has an important role in enhancing the competence of a country in the global market place. Governments, especially in most developing countries, are increasingly realizing that the poor services provided by their national ports and their high costs are hampering trade development and the national economy (Haralambides, 2003). Improving the performance or efficiency of container port improves the country's international market access and leads directly to increase trade and through this, to higher income.

Container terminal could be seen as a gateway or as a node in globalized supply chain that serves domestic and international freight movement. Logistic and supply chain era demands reliable and accurate services in order to allow manufacturing industries to adopt just in time and make to order production technology. These technologies enabled companies to cope with the vagaries and unpredictability of the seasonal, business and trade cycles (Haralambides, 2003).

Shipping world ask container terminal for improvement in cargo handling operation to reduce its port time and to ensure that the saving at sea with post-panamax vessels are not to be lost on terminal. It is why shipping lines are eager for expanding their scope to include terminal operation and hinterland transportation (Notteboom, 2001).

Efficiency often means speed and reliability of port services. Port efficiency can be reflected in the freight rates charged by shipping companies, turn round time of ships and cargo dwelling time. In international trade where products must be moved to market on time, terminal operators should be in position to guarantee shipping line with a reliable service. These guarantees include guarantee on turn round time and connection for vessel.

Port efficiency and port performance measurement is a term difficult to define because of perception differences among stakeholders. For examples, shipping line and manufacturing industries ask for speed of turn round time and cargo dwelling time, government ask for higher throughput and investors ask for maximizing profit. Bichou (2007) cites that over the last three decades or so, there has been a growing amount of both theoretical and practical work on port performance measurement and benchmarking. Relevant work on mechanisms and techniques of port performance and efficiency has taken place at different disciplinary levels, yet with fragmented layers of operational, functional and spatial port systems. Fundamental differences between these conflicting approaches and their proposed methodologies meant that, despite the variety of tools and instruments available, no consensus on single framework for port performance benchmarking has been established.

Furthermore Bichou (2007) gives an examples of the differences, there are:

- Differences on the definition and taxonomy of performance for instance efficiency, productivity, utilization and effectiveness;

- Perceptual differences among multi institutional port stakeholders and the resulting impact on the objectives, design and implementation of performance frameworks and analytical model;
- Boundary spanning complexities of seaport operational;
- Dissimilarity, in both space and time, between world ports operational structures, functional scopes, institutional models and strategic orientation

Differences of techniques and methodologies in port efficiency measurement have been realized due to complexity to relate between input and output. Input and output are very varied and wide including laborers, equipment, hydrographical attributes, information and communication technology and others, and outputs include volume of traffic handled, number of port personnel trained, and others. Such complexity is going to make port performance standard difficult to be defined like manufacturer standard.

Data Envelopment Analysis (DEA) is a mathematical technique for linking input-output ratio. In economics the ratio is called as efficiency. Using linier programming, this method can calculate multiple inputs and multiple outputs. The method become popular and then adopted for measuring port efficiency and for benchmarking port industry.

Indonesia, as an archipelagic country, has at least 12 container terminals which are managed by private, most of them are owned by government. Until now, there has never been a study or evaluation to assess the performance of container terminal. This is easily understandable because the containers going through the terminal are captive and the competition between container terminals is limited. However, in this era of trade globalization, assessing the performance of container terminal in Indonesia needs to be done urgently in order to sharpen the country's competitiveness.

The only study associated with DEA in evaluating port efficiency was done by Nugroho Purwantoro R, (2004) by analyzing 24 ports in Indonesia, using BCC model. This study used 4 variables of outputs, there are 2 ship call variables, both in units and weight, 2 cargo flow variables, both in tonnage and in TEU's. Input used in this study consists of 23 variables involving each kind of asset used in port, which is categorized in 4 groups, namely infrastructure, ship, handling equipment and haulage equipment. He concluded that 8 out of 24 ports evaluated are not efficient related to the others.

The aim of the thesis is to measure container terminal's efficiency in Indonesia for its improvement in the future. Information on efficiency rating is likely to be a powerful tool as benchmarking for container terminal management in assessing the performance of their ports. The information is also could be used by government (and PT. Pelindo as the owner) in allocating fund and encouraging container terminal management for better performance in the future.

The evaluation will be performed by applying Data Envelopment Analysis (DEA), a non parametric approach, to reflect input and output relationship. DEA is one of the famous techniques to measure efficiency. This method has been widely utilized to analyze relative efficiency and has covered a wide range of application.

1.2 Research Questions

In Indonesia, a terminal can be called as container terminal if the terminal is minimal equipped with one gantry crane and has 2 hectare of container yard (Ministerial decree no 54 year 2002 about Seaport). According to the regulation, container terminals in Indonesia are relatively uniformed and have similar equipment. A port can't be classified as container terminal although it is used as loading and unloading for container cargo.

There are three parties managing container terminals in Indonesia. First is state-owned company, second is fully private companies and the third is mixture between state-owned company and private company. Three of them are managed by a joint venture between stated-owned company and private company, one of them is managed by fully private company and the rest is managed by state-owned company.

The basic question of the thesis is how to find out container terminals efficiency in Indonesia. Which container terminal is relatively more efficient comparing to the others and which are not efficient. The samples used are 12 container terminals in Indonesia which have throughput ranges between 100 thousands TEUs to 2 million TEUs. Two out of these 12 terminals have throughput more than 1 million TEUs, Four of them has throughput between 500 thousands TEUs to 1 million TEUs and the rest have throughput below 500 thousands TEUs.

The next question is how to know and examine the causes of both efficiency and inefficiency. Examination is limited to the input used in the research. The inputs are length of berth, number of gantry cranes, yard area and number of employees where output used is throughput in term of TEUs. Theoretically, container terminal located in Jakarta and Surabaya would be more efficient because they serve big ships and are supported by high growth of regional economic activity.

The question could be extended on which container terminals are well-managed between three parties managing container terminals in Indonesia. Of course it would become a big issue in Indonesia.

1.3 Research Methodology

To fulfill the objective of research, the methodologies used will be following:

- Research on literature related to the DEA application in evaluating port's efficiency. It performs to find out which ports are analyzed, what DEA type is performed, what inputs and outputs are used and what the result is. This step is done in order to decide number of container terminal to be analyzed, kind of DEA model to be performed, type of inputs and outputs will be analyzed.
- Interview and making correspondence to collect data input and output and to make sure that the data collected is valid. This step is done carefully to prevent garbage input to be collected.

- Performing DEA application to analyze input and output collected. Result provided is expected to present efficiency rating as long as the validity of the data input could be managed.
- Analyzing DEA application's results is an interesting section. Could the recommendation be applicable is an interesting question because container terminal has to fulfill minimum asset requirement even it is not productive.

1.4 Thesis Structure

The thesis consists of five chapters, namely introduction, Port efficiency, Research methodology and data collection, DEA application result, Relation between DEA application result with existing condition of each port and Conclusion and recommendation.

In chapter 1, Introduction, elaborates background and objectives of this thesis and describes a little bit about DEA application. The thesis question is also presented to address to which direction where the research is going. And the last this chapter also elaborates the step to be taken in analyzing efficiency of container port.

Chapter 2 will describe efficiency theory, port efficiency measurement and study conducted using DEA technique in port field. This chapter also elaborates determinants of port efficiency as studies result.

Chapter 3 introduces research methodology used and data collected. In this chapter the modeling technique, DEA approach, will be briefly discussed. This chapter also presents how data is collected, what is the consideration in selecting samples and consideration in selecting input-output variables.

Chapter 4 provides result and analysis. The efficiency rank will be presented and analysis of the result will be deeply elaborated. Elaborating will cover all information provided by DEA Frontier such as number of slack, peers and ideal inputs (target) of each terminal.

Chapter 5 relates results of DEA application and existing condition of each port. This chapter will discuss DEA result of each container terminal and whether the recommendation can be implemented in accordance with the characteristic of each terminal.

Chapter 6 concludes the study and some recommendations will be presented.

Chapter 2 Port Efficiency

2.1 Introduction

This chapter tries to give a description about port efficiency. The most interesting question is how to measure port efficiency. Many studies have performed to define port efficiency and many studies have done to measure it but until now there is no acceptable definition and measurement standard. This chapter attempts to answer the following question.

- What is efficiency?
- What is port efficiency and how to measure it?
- What study is performed in attempting to measure port efficiency?
- What study is performed to measure port efficiency in Indonesia?

2.2 Efficiency Measurement

Efficiency is important indicator in measuring company performance. The concepts of efficiency involve the relationship between inputs and output that is how to allocate factors of production in such away in order to maximize output. A company is deemed to be efficient if it can produce high output with the use of certain input or can produce a specific output using fewer inputs.

Principally efficiency of a company consists of two components: technical efficiency and allocative efficiency. Technical efficiency is company's ability to produce maximum output using a particular input. While the allocative efficiency is company's ability to use input with optimal proportion at certain level price of output. Then the two components are combined to measure the total efficiency or economic efficiency (Farrel, 1957).

Technically efficiency can be approached from two side, input-oriented approach and output-oriented approach. Input oriented approach is by how much input quantities can be proportionally reduced without changing the output quantities produced. While output oriented approach is by how much output quantities can be proportionally expanded without altering the input quantities used (Coelli, 2005). The two views of technically efficiency further divide measurement concept into two approaches, input-oriented measures and output-oriented measures.

Acceptable efficiency measurement is a difficult term to be formulated. Industries want to know how many outputs can be increased without absorbing its resources or at given output how far resources could be reduced. At the beginning efficiency is measured with average productivity of labor that is output per labor ratio. This measurement is seen unsatisfactory because avoiding other inputs used. Then efficiency measurement is developed as indices of efficiency, in which average of inputs is compared with output. These attempts have naturally run to all index number problems (Farrel, 1957).

Farrel (1957) first introduced efficiency measurement concept which takes into account all inputs and avoid index number problem. He applied first to compute efficiency in agricultural field. And now, supported by information technology, his concept has emerged and has been used as efficiency measurement in many industries.

In general, efficiency measurement is categorized into two groups: partial productivity measure and total factors productivity measures (Cooper, 2007). Partial productivity measure is a simple computation for calculating ratio of single output and single input, for example output per worker hours. Total factor productivity measure combines all inputs and all outputs to single ratio to avoid imputing gain to one factor that are attributable to some other factor.

2.3 Port Efficiency Measurement

In the last thirty years the literature on efficiency and productivity measurement in the container terminal industry has become substantial. UNCTAD (1999) distinguished between two categories of performance indicator in the context of ports and terminal: macro performance indicator that focuses on aggregate impacts of port activities and micro indicator that aim at quantifying input-output ratio (Acciaro, 2010).

In the micro perspective the port efficiency measurement could be approached into a single-port performance evaluation approach and multiport performance evaluation approach. Single-port approach may be done by comparing the port's actual throughput to its optimum throughput or comparing the actual values of its performance indicator to the standards of these indicators over time. Meanwhile in multiport performance evaluation approach, the performance of one port is compared to the others (Talley, 2007).

Comparison performance of one port to another may be misleading because ports operate in different economic, social and fiscal environment. That is why researcher recently relies on frontier statistical model. The frontier approach measures the efficiency in relation to the calculation or estimation of a frontier. Under this approach, a firm is defined as efficient when it operates on the frontier and inefficient when it operates away from it (below it for a production frontier and above it for a cost frontier). The frontier can be absolute or relative (i.e. best practice) depending on the method of parametric construction, i.e. parametric versus non-parametric method.

Parametric, or econometric, methods require a functional from whereby a set of input and output observations can be statistically estimated. Parametric models refer to the calculation or estimation of a cost or production frontier function from the input-output data, meaning that parameter values can be statistically inferred from data observations. The parametric representation can, however, be either deterministic or stochastic, depending on whether or not certain assumptions are made regarding data used.

Non-parametric approaches do not require a pre-defined functional formulation but use linier programming techniques to determine rather than estimate the efficiency frontier. Much of the recent research in the field involves the use of data envelopment analysis (DEA). The methodology works by solving a series of linier programming problems and selecting the optimal solution that maximizes the efficiency ratio of weighted output to weighted input for each DMU (Decision Making Unit).

Acciaro (2010) cites that a large portion of the literature has focused on Data Envelopment Analysis (DEA) due to the major advantages the method has such as it does not require any probability assumption, it is rather flexible and it can easily account for a multiple inputs and outputs. The weakness of this method is that it does not provide any error measurements being deterministic in nature and is subjected to rather heavy bias from outliers.

2.4 Related Study Applying DEA Application

Related study applying DEA application to port performance has been done since 20 years ago when Roll and Hayuth (1993) applied DEA-CCR model to examine 20 ports using hypothetical data. Up to now hundreds of studies have been conducted with various type of DEA, various inputs and outputs and various ports as the object observed. In general, these studies attempt to link efficiency and its determinants by combining DEA application and other methods like Tobit regression.

Study Related Determinants of Efficiency

The study concludes that port efficiency has strong relationship with port size and port geographical. The conclusion stems from Martinez-Budria (1999) when analyzing 26 Spanish ports using DEA-BCC model. The ports are categorized into three groups: high complexity ports, medium complexity ports and small complexity. The input used is labor expenditure, depreciation charge and other expenditure. The output used is cargo moved in dock and revenue from port facilities rent. They concluded that high complexity ports are associated with higher efficiency.

Barros (2003b) also found that efficiency scores are related to container handling, scale (throughput) and market share. He studied ten Portuguese seaports from 1990 to 2000 using DEA-Malmquimist and Tobit regression model in order to identify the source of any inefficiency.

The other study, Cullinane and Wang (2006) also shows that there was significant efficiency in the European container terminals observed and large container terminal is likely to be associated with higher efficiency scores. They focused the study on container terminals in Europe using DEA application. Number of container terminals observed is sixty nine across twenty four countries with annual throughput over 10,000 TEUs for year 2002. The output selected is throughput (TEUs) and the input selected is terminal length, terminal area and number of equipment.

Unlike the others, Tongzon (2001) resulted that port size is not primary determinant of port efficiency. He used DEA-CCR and DEA-Addictive model to calculate efficiency of four Australian and 12 other international ports. The output used is cargo throughput and ship working rate and the input used is the number of berth, cranes and tugs, the number of stevedoring labor, terminal area and amount of delay time at berth. He found that port of Melbourne, Rotterdam, Yokohama and Osaka were the most inefficient ports and the result indicated that port size or function alone is not the primary determinant of port efficiency. But he doubted the result of study and realized that the results were not accurate because of poor data collection and small number of observation.

The second determinant of port efficiency is privatization. Barros and Athanassiou suggested that appropriate way to achieve scaled economies is through privatization.

They studied relative efficiency of 2 Greek ports and 4 Portuguese ports by applying DEA-CCR and DEA BCC in order to seek out the best practice that will lead to improve performance with context to the European Seaport policy. They used number of workers and capital (book value of assets) as inputs and movement of freight, cargo handled, container handled and number of ships as output. The result shows that the majority of seaports are efficient and suggests that scale economies would be the solution to increase performance and the most appropriate way of achieving scaled economies is through privatization.

The same conclusion stems from Demirel (2009) that private sector involvement in the container terminal operations and scale effect are associated with higher efficiency. He combined DEA application and Tobit regression model to investigate impact of private sector involvement in container terminal operations on port (terminal) efficiency in Turkey. The number of port (terminal) observed is 47 located in Turkey and Eastern Mediterranean. The output selected is throughput and inputs are Quay length, terminal area, number of quay cranes, yard equipment and draught.

The other determinant of efficiency is better incentive of production. Barros (2003a) applied DEA to five Portuguese ports in order to investigate effectiveness of the state's policy regarding incentive regulation policy in achieving its aim. The input selected is number of employees and book value of assets. The output selected is movement of freight, gross tonnage of ship, Ro-Ro traffic, market share, break bulk cargo, containerized cargo, dry bulk, liquid bulk and net income. He concluded that the incentive regulation was not achieving its aim.

Efficiency Study in General

Many studies apply DEA application to various ports or terminals in the world. For example, Zegordi and Nahavandi (2002) studied productivity and efficiency at Port Rajaei; Rios, L. R. (2006) analyzed the relative efficiency of operation in container terminals of Mercosur in year 2002, 2003 and 2004; Hussain (2008) analyzed performance of some ports from Middle East and African port. The interesting point of these studies is there are many differences of type of data input and output, differences in DEA model used and comparing different type of port.

Koster (2009) compared efficiency scores from the benchmarking exercise with those of previous studies. As predicted before, the results differ strongly from those available in the literature. Causes for these differences are public data which are not always accurate, different terminal type are compared, terminals of different scale are compared and terminal are mixed with ports. He studied efficiency of 38 container terminals owned by APMT and HPH. Input selected is number of gantry cranes, Quay length and yard area while output selected is throughput (TEUs).

Study Related Applying DEA Application in Indonesia

In Indonesia, the only study related applying DEA application on port was performed by Purwantoro (2004). He measured relative efficiency of 24 ports using DEA-BCC model.

He used 27 variables which then categorized into 4 groups of input, infrastructure, lifting equipments, haulage equipments and ships (tug boat). The output he used consists of 4 outputs, number of ships call, ships call (in GT), cargo throughput and container throughput. In selecting ports to be observed, he neglected port size and specialization, so the cruising small port like Nunukan is mixed with Tanjung priok port. The result shows that 8 out of 24 ports observed are not efficient without further explanation.

2.5. Determinants of Container Terminal Efficiency

Mathematically, efficiency could be defined as output divided by inputs. In container terminal industry, output used is usually throughput and input used is various resources like length of berth, number of labor, number of cranes and others. Many studies conducted to find out determinants of efficiency in principally are to find out factors influencing these inputs and output of terminal efficiency.

The interesting point is from the output side, throughput, due to this factor cannot be completely influenced by management like input side. Tongzon (1995) cites that cargo size or throughput is determined by following factors:

- Geographical location of a port has an impact on cargo size. Transshipment port like Singapore and Rotterdam has different cargo size from Jakarta which is driven by an isolated and regional economy.
- Frequency of ship calls is attractive to importers and exporters and ranked first for port choice.
- Port charges is also a determinant of throughput but more important shippers are concerned with indirect cost like delay, loss of markets due to inefficiency cargo handling.
- Economic activity level at the region port located has direct effect on the level of demand for port services.
- Terminal efficiency, which in turn determined by container mix, work practice, crane efficiency and vessel size and cargo exchange.

Cohcrane (2008) showed that terminals may have significantly different throughput in TEU due to market differences although such terminals using similar management methods and operating at similar levels of operational efficiency. His conclusion arrived after observing terminals in Yantian and Hong Kong which serve manufacturing centre in Pearl River Delta. Factors considered affecting throughput include vessel size, the number of container moves per vessel proportion of containers of differing size and relative size of the transshipment and landed container market.

Due to throughput is the main determinant of container terminal efficiency, Cohrane (2008) suggests to disaggregate throughput into separate outputs, at least by container size, by land and transshipment intermodal categories when using frontier technique to measure port efficiency. The step is to minimize effect of market differences on throughput of container terminal.

Chapter 3 Research Methodology

3.1 Introduction

This chapter presents methodology used to measure container terminal efficiency, Data Envelopment Analysis (DEA), and presents data collection and data collection approach. What will be discussed in this chapter is in order to answer the following question.

- What is DEA application?
- How is it operated?
- What are the strengths and weaknesses of DEA application?
- What are the inputs and outputs and how are they determined?

3.2 Data Envelopment Analysis

Data Envelopment Analysis (DEA) was stemed from a Ph.D. dissertation done by Rhodes in 1978 which was supervised by Cooper and Charnes. Rhodes examined the efficiency of educational institutions in the New York City district and then the resulting model is named CCR. It is an extension of technical efficiency measure from Farrel (1957).

Following the CCR, in 1984, Banker, Charnes and Cooper introduced BCC model by adding constraint of convexity which allows DMUs to be measured on a variable-return-to-scale basis. Nowadays DEA has been expanded to be used to study the relative efficiency of over 50 industries including banking, fast food, healthcare, insurance, credit unions, highway road maintenance, and capital budgeting projects and over 1,300 papers have been written by academics.

Data Envelopment Analysis (DEA) is a technique using linear programming for calculating total factor productivity measures. The measurement attempts to calculate input-output ratio value, as efficiency measurement, which takes the account of all inputs and all outputs. The total-factor productivity measure is used to distinguish them from partial productivity measures. It is a traditional measurement for calculating efficiency index or firm productivity by relating single input and single output, for example cost per unit, output per worker and so on (Cooper, 2007).

The use of linear programming allows DEA not just to consider multiple inputs and outputs simultaneously but also calculate the relative performance of a population of firms or units referred to as decision-making units (DMUs). That is why DEA technique is widely used as benchmarking tool and efficiency measurement tool of a group of companies or population of units. The basic assumption behind this method is that if a given unit is capable of producing Y(A) units of output with X(B) inputs then the other units should also be able to do the same if they were to operate efficiently (Hussein, 2008).

DMUs which operated efficiently form frontier line and called as efficient frontier or envelopment surface. It is such as best practice of efficient DMU in its group. Furthermore, DEA constructs and calculates efficiency scores of each DMU based on its distance to frontier line. The scores indicate how many percent a DMU can increase its output without consuming more inputs or how many percent a DMU can decrease its input and maintain its current output.

3.2.1 Mathematical Model

A simple expression of efficiency measurement of single output and single input can be mathematically described below:

$$\text{Efficiency} = \frac{\text{output}}{\text{Input}}$$

If a firm has multiple input and multiple outputs, the expression is:

$$\text{Efficiency} = \frac{\text{weighted outputs}}{\text{Weighted inputs}}$$

The formulation above shows efficiency range between 0 and 1 (or 0 to 100%). The problem now is how to determine weights. To answer the question we come to the two most prominent models of DEA methodology, CCR and BCC ratio models.

Below is presented mathematical model from Coelli (2008) to describe DEA-CRS and DEA VRS.

The CCR Ratio Model (CRS)

Coelli (2008) describes mathematical model for DEA-CCR as follow. Assume there is data on K inputs and M outputs on each of N firms or DMU's as they tend to be called in the DEA literature. For the i-th DMU these are represented by the vectors x_i and y_i, respectively. The KxN input matrix, X, and the MxN output matrix, Y, represent the data of all N DMU's.

For each DMU that it has to be obtained a measure of the ratio of all outputs over all inputs, such as u'yi/v'xi, where u is an Mx1 vector of output weights and v is a Kx1 vector of input weights. In selecting optimal weights the mathematical programming denotes below:

$$\max_{u,v} (u'y_i/v'x_i),$$

$$\text{st} \quad u'y_j/v'x_j \leq 1,\ j=1,2,\ldots,N,$$

$$u, v \geq 0.$$

This involves finding values for u and v, as such the efficiency measure of the i-th DMU is maximized, subject to the constraint that all efficiency measures must be less than or equal to one. One problem with this particular ratio formulation is that it has an infinite number of solutions. To avoid this one can impose the constraint $v'x_i = 1$, which provides:

$$\max_{\mu,v} (\mu' y_i),$$

$$\text{st} \quad v'x_i = 1,$$

$$\mu' y_j - v'x_j \leq 0, \; j=1,2,\ldots,N,$$

$$u, v \geq 0,$$

where the notation change from u and v to μ and v reflects the transformation. This form is known as the *multiplier* form of the linear programming problem.

Using the duality in linear programming, one can derive an equivalent envelopment form of this problem:

$$\min_{\theta\lambda} \theta,$$

$$\text{st} \quad -y_i + Y\lambda \geq 0,$$

$$\theta x_i - X\lambda \geq 0,$$

$$\lambda \geq 0,$$

where θ is a scalar and λ is a Nx1 vector of constants. This envelopment form involves fewer constraints than the multiplier form ($K+M < N+1$), and hence is generally the preferred form to solve. The value of θ obtained will be the efficiency score for the i-th DMU. It will satisfy $\theta \leq 1$, with a value of 1 indicating a point on the frontier and hence a technically efficient DMU, according to the Farrell (1957) definition. Note that the linear programming problem must be solved N times, once for each DMU in the sample. A value of θ is then obtained for each DMU.

The BCC Model (VRS)

The CRS assumption is only appropriate when all DMU's are operating at an optimal scale (i.e one corresponding to the flat portion of the LRAC curve). Imperfect competition, constraints on finance, etc. may cause a DMU to be not operating at optimal scale. Banker, Charnes and Cooper (1984) suggested an extension of the CRS DEA model to account for variable returns to scale (VRS) situations. The use of the CRS specification when not all DMU's are operating at the optimal scale will result in measures of TE which are confounded by *scale efficiencies* (SE). The use of the VRS specification will permit the calculation of TE devoid of these SE effects.

The CRS linear programming problem can be easily modified to account for VRS by adding the convexity constraint: $N1'\lambda=1$ to (12) to provide:

$$\min_{\theta,\lambda} \theta,$$

$$\text{st} \quad -y_i + Y\lambda \geq 0,$$

$$\theta x_i - X\lambda \geq 0,$$

$$N1'\lambda=1$$

$$\lambda \geq 0,$$

where N1 is an Nx1 vector of ones. This approach forms a convex hull of intersecting planes which envelope the data points more tightly than the CRS conical hull and thus provides technical efficiency scores which are greater than or equal to those obtained using the CRS model.

Calculations of Scale Efficiencies

Many studies have decomposed the TE scores obtained from a CRS DEA into two components, one due to scale inefficiency and one due to "pure" technical inefficiency. This may be done by conducting both a CRS and a VRS DEA upon the same data. If there is a difference in the two TE scores for a particular DMU, then this indicates that the DMU has scale inefficiency, and that the scale inefficiency can be calculated from the difference between the VRS TE score and the CRS TE score.

Figure 1 attempts to illustrate this. This figure shows a one-input one-output example and the CRS and VRS DEA frontiers have been drawn. Under CRS the input-orientated technical inefficiency of the point P is the distance PP_C, while under VRS the technical inefficiency would only be PP_V. The difference between these two , P_CP_V, is put down to scale inefficiency. One can also express all of this in ratio efficiency measures as:

$$TE_{I,CRS} = AP_C/AP$$

$$TE_{I,VRS} = AP_V/AP$$

$$SE_I = AP_C/AP_V$$

Where all of this measures will be bounded by zero and one. We also note that

$$TE_{I,CRS} = TE_{I,VRS} x SE_I$$

because

$$AP_C/AP = (AP_V/AP)x(AP_C/AP_V)$$

That is, the CRS technical efficiency measure is decomposed into "pure" technical efficiency and scale efficiency.

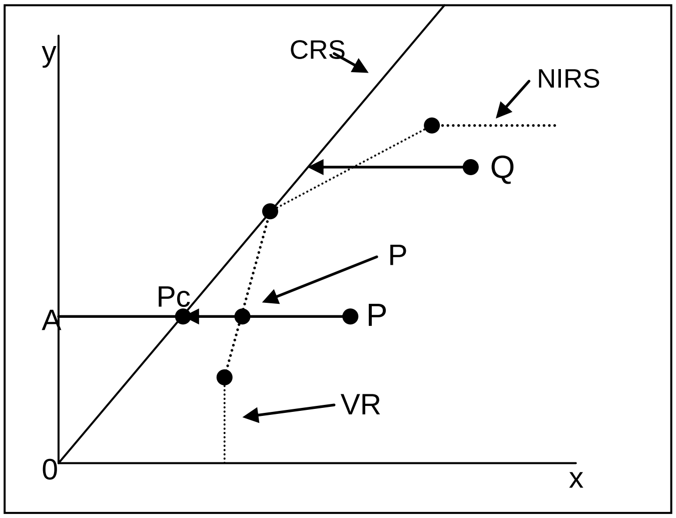

Figure 1: Calculation of scale economies in DEA
Source: Coelli (2008)

3.2.2 Differences between DEA-CRS and DEA-VRS

The CCR model assumes production frontier following constant returns to scale (CRS). The assumption illustrates that any increase in one input results in a proportional increase in at least one output or a proportional decrease in one or more inputs must decrease output at the same proportionally level of input.

The CCR ratio model focuses on the identification of the overall efficiency of the DMUs studied. It also identifies the sources and estimates the potential improvements available for the inefficient DMUs. It is important to note that CCR model provides the envelopment surface that represents CRS.

DEA-VRS model is an extension of DEA-CRS which assumes all DMUs are operating at variable return to scale because of imperfect competition, constraints on finance, etc. It implies that some DMUs are operating at increasing return to scale, some are operating at constant return to scale and the rest are operating at decreasing return to scale.

The DEA-VRS model distinguishes between technical and scale inefficiencies by estimating pure technical efficiencies at the given scale of operation and by identifying whether increasing, decreasing or constant returns to scale possibilities are present for further exploitation. This model interprets the efficiency of the DMUs with the underlying assumption that the VRS mechanism exists among the population of observations. It incorporates the notion that an increase in the inputs does not necessary translate to the same proportional increase in outputs throughout all scales of operation.

This is different from the CCR mode, which assumes the input and output relationships of all DMUs exhibit a proportional or a linier relationship for all scales of DMUs. The BCC model allows the DMUs with varying scale sizes to be compared in the same DEA analysis. This is a result of the BCC model being technically efficient while CCR is scale and technically efficient. Technical efficiencies are efficiency measures that ignore the impact of scales size by comparing a DMU only to the other unit of similar scale. On the other hand, scale efficiency depends on the size of operations and makes this optimal. Any modification to the size will cause the unit to be less efficient.

The important difference between DEA-CRS and DEA-VRS is that efficiency score provided by DEA-CRS is less than provided by DEA-VRS. In DEA-CRS, there are less efficient DMUs comparing with DEA-VRS. That is the impact of adding the convexity constraint: NIλ=1.

3.2.3. Strengths and Weaknesses of DEA Application

Demirel (2009) has summarized strengths and weaknesses of using DEA application for measuring port performance. The advantages are:

- DEA provides the possibility to measure efficiency with multiple inputs and multiple outputs.
- It has no assumption regarding the functional form of the efficient frontier and distribution of error. The efficient frontier extracted from DEA is based on the best observed units rather than measures of central tendency.
- It is not necessary to know the type of production function in advance.

While weaknesses of using DEA application is summarized below (Demirel (2009).

- Since DEA is a deterministic approach, it takes no account of possible influences of measurement error and other noise in the data.
- Efficiency scored obtained is not absolute efficiency values, but change depending on data set. DEA implies a relative efficiency for a DMU, compared to all other DMU's in the sample.
- DEA asks for homogeneity data, all the DMU should have the same input and same output.
- DEA ask for *isotonicity* that is the output must not decrease while the input increases.
- DEA has also the deficiency of identifying the causes of the in(efficiency). DEA identifies the slacks for the efficient DMUs and gives to each DMU a reference set of peer which allows for specific recommendations to improve efficiency Barros and Athanassiou, 2004).

The limitations above make us to be careful when using DEA application to measure port efficiency. *Isotonicity* limitation is difficult to be fulfilled. Container throughput is not just influenced by terminal efficiency but also influenced by many factors like geographical location, frequency of ship calls, port charges and the main driver is economic activity. For example in 2008 because of economic crisis, throughput of almost container terminals in the world was decrease meanwhile input used remain the same. Of course it doesn't mean that efficiency is decrease.

Homogeneity data as asked by DEA requires researcher to be careful in selecting sample observed. It has to be ensured that characteristic of ports compared is homogeny like comparing among transshipment container terminal.

And the important thing is that application of DEA technique on port usually uses fixed assets for input, like terminal length, terminal equipment number and terminal area. DEA recommendation to improve efficiency, if a DMU is marked as inefficient, by increasing or decreasing these assets is difficult to be fulfilled in real business. Selling and buying fixed assets cannot be done in a short period.

3.3 Data Collection

Regarding to the limitations of DEA application, the important step in this respect is data collection. Researcher must give more attention to the units of analysis (terminal, ports or mix), type of data, the DEA model and the input output variables. Koster (2008) finds that several studies do not have consistent units of analysis, for example comparing container terminal with complete port or comparing small terminal with the big one. He also criticizes the reliability of public data used as sources and no agreement of DEA model used and input-output variables used.

Regarding to Koster's criticism, data collection for this study is collected carefully particularly when collecting data observed and deciding units of analysis. Below is presented steps in collecting data for the research.

The size of DMUs

There is no rule on the minimum size of sample must be taken. As an example Barros (2003b) takes 5 Portuguese ports and Cullinane (2006) examined 67 Europe ports. Although more samples used will form best practice frontier more accurate and better and approach the reality of population efficiency frontier.

Demirel (2009) when evaluating private container terminals efficiency in Turkey advises that the sample size is at least twice the sum of the inputs and outputs, as a rule of thumb. He also shows that some studies advice even more conservative approach like Cohcrane (2008) mentions a minimum size data set of at least three and preferably four times of the total number of input and output parameters. Cooper, Seiford and Tone (2000, 2006) made a formula regarding minimum sample size.

Data

The data used is primary data related to 2007-2009 period and will be averaged to minimize the impact of 2008 crisis which did not suffer each container terminal and to avoid *isotonicity*.

The data is collected via email to each container terminal management and validated by self experience. Communication with management of terminal was performed when data obtained via email is less convincing.

Unit of Analysis

The unit of analysis is 12 container terminals in Indonesia that handle between 100 thousands TEUs to 2 million TEUs per year. It seems to vary greatly but the size of ships serviced just varies from 400 TEUs per ship up to 1600 TEUs per ship. Terminals are also located both at river port and seaport. The difference is not a problem because of similarity of container terminals in Indonesia.

In Indonesia, a terminal could be called as container terminal if it has fulfilled some requirements such as having minimal 100 m berth, 1 gantry crane, 2 ha container yard and other requirement as stated in Shipping Law no 12 year 2002. Therefore container terminals in Indonesia have similar equipment and facilities and of course have similar production processes.

All container terminals selected also have captive market. Proportion of the transshipment containers is very small, for example in JICT container terminal and Koja container terminal which are located in the main port of Tanjung priok have just around 1-2 percent of transshipment containers.

Variables

In this study, input and output variables are one output and four inputs. The output is terminal's throughput in term of number of TEUs. The inputs are length of berth, number of employee, number of gantry cranes and yard area. The considerations in selecting inputs and output are:

- Throughput in term of TEUs is mostly used in majority study investigating container terminal efficiency. And beside to maximize profit, the objective of container terminal management is to maximize total throughput. The size of container terminal could be seen from its throughput.
- Three inputs variables, number of gantry cranes, total quay length (in meters), terminal area (in hectare) are used in all papers investigating container terminal efficiency. Beside that they are also the main factors of production in container terminals.
- The number of employee is used as variables although Notteboom et al. (2000) suggests that employee factor can be dropped because of close relationship between the number dockworkers and the number of gantry cranes. In my experience it is also determinant factor to maximize berth productivity.

Execution

This thesis will perform both DEA CRS and DEA VRS with input-oriented approach under consideration that all container terminals still have spaces for increasing their production except Pontianak's container terminal which has limited area for development. By input-oriented approach, analysis is addressed to examine the ideal input at the current output. Measurement is performed by DEA Frontier software developed by Joe Zhu.

Summary of input-output characteristic considered is presented in table below:

Table 1: Summarize of input and output

	Throughput TEUs	Length of Berth	Number of Gantry cranes	Terminal Area (m2)	Number of Employees
Mean	485,270.28	703.06	5.00	156,966.28	276
Median	301,423.50	494.00	4.00	72,250.00	144
Standard Deviation	508416.6668	552.34016	3.927922	183060.8298	289.1009
Sample Variance	2.58388E+11	305079.65	15.42857	33511267394	83579.34
Kurtosis	2.32598178	1.7818188	1.80303	4.714136427	1.076868
Skewness	1.722094558	1.5876842	1.470617	2.243128759	1.384308
Range	1.907.312	1.984	16	682.680	985
Minimum	78,469.00	182	1	17,320	35
Maximum	1,985,781.00	2,130	17	700,000	1,020
Sum	17,469,730.00	25,310	180	5,650,786	9,935

Source: own elaboration

From the data summary above, it seems terminals observed vary greatly. As explained before, the size difference is minimized by similar characteristic of terminals, like similar technology, captive market, wage standard and similar management. The data summary above also presents the homogeneity requirement of DEA application is met because all the DMUs observed have the same inputs and output, in this case all DMUs are container terminals. The positively requirement is also fulfilled because the terminals always produce positive cargo throughput.

Chapter 4 DEA Frontier Results

4.1 Introduction

Measurement of efficiency level of container terminals in Indonesia is done by applying DEA Frontier software developed by Joe Zhu. Measurement is performed by two models of DEA, DEA-CRS and DEA-VRS. The aim is to separate technical efficiency resulting from DEA-CRS into two components, 'pure' technically efficiency resulting from DEA-VRS and scale efficiency of each container terminal to achieve optimal efficiency.

The main questions of this chapter which are trying to answer:

- What is efficiency score of each container terminal?
- What improvement should be done by each container terminal to achieve efficiency level?

4.2 Result

Efficiency scores of container terminals in Indonesia are computed by applying DEA Frontier solver which was developed by Joe Zhu. Calculation is based on DEA-CCR (CRS) and DEA-BCC (VRS). The use of DEA VRS is under consideration that not all container terminals are operating at the optimal scale. It can be seen that container throughput varies from 100 thousand TEUs to 2 million TEUs. In DEA-CRS, a firm may be benchmarked against firms that are substantially larger (smaller) than it whereas in DEA-VRS, an inefficient firm is only benchmarked against firms of similar size (Coelli, 2007).

DEA-CCR calculates the overall efficiency, both technical and scale, of the DMUs and also identifies the sources and estimates potential improvements available for the inefficient DMUs. Meanwhile DEA-BCC estimating pure technical efficiency at the given scale of operation and identify whether increasing, decreasing and constant returns to scale possibilities are present for further exploitation.

Technical efficiency reflects the ability of a port to maximize its outputs from a given set of inputs. Scale efficiency is the overall economic efficiency. The analysis was carried out on 12 ports and efficiency scores obtained are illustrated in the table below.

Table 2: DEA application Result

Port	CRS	VRS	Scale	Return to Scale
Jakarta International Container Terminal	1	1	1	Constant
Koja Container Terminal	1	1	1	Constant
Mustika Alam Lestari (MAL)	1	1	1	Constant
Serbaguna Container Terminal (MTI)	0.53706	0.54036	0.99389	Increasing
Palembang Container Terminal	0.97149	1	0.97149	Increasing
Panjang Container Terminal	0.92384	1	0.92384	Increasing
Pontianak Container Terminal	1	1	1	Constant
Belawan Container Terminal	0.88191	0.88251	0.99932	Increasing
Terminal Petikemas Surabaya (TPS)	0.95842	1	0.95842	Decreasing
Terminal Petikemas Semarang	0.84887	0.88893	0.954935	Decreasing
Terminal Petikemas Makassar	0.97312	1	0.97312	Decreasing
Terminal Petimekas BITUNG	0.94553	1	0.94553	Increasing

Source: Own elaboration

Efficiency Scores

Using DEA-CRS for calculating container terminal efficiency, four terminals are noted as efficient terminal and eight terminals are inefficient terminals. The efficient terminals are JICT, Koja, MAL and Pontianak container terminal. JICT, Koja and MAL are located in largest port, Tanjung Priok, and serve big ships for international trade. Pontianak is a river port and located in west Kalimantan. As river port, Pontianak container terminal serves small ships having around 100 meters length.

Except Serbaguna container terminal, level of efficiency of the other port is in the range from 85% to 97%. Serbaguna is the most inefficient container terminal as its level of efficiency is just 54%. The result can be understood because channel to Serbaguna is narrow so the ships are reluctant to come.

Under DEA-VRS model, nine terminals are noted as efficient terminals. The inefficient terminals are Serbaguna, Belawan and Semarang container terminal. These terminals could be said as technically inefficient.

The model used in this respect is input oriented therefore inefficiency means that these terminals have excess resources at the level of its output. Theoretically, to achieve efficiency these terminals should remove their slacks and reduce their inputs, for example Serbaguna container terminal should remove its slack, around 1 ha of yard area, and should reduce its inputs around 45%.

Naturally, efficiency score under DEA-VRS is bigger than efficiency score under DEA-CRS. So the number of efficient terminal under DEA-VRS is more than the number of efficient terminals under DEA-CRS. Furthermore efficiency score under DEA-CRS is decomposed into pure technically efficient and scale efficient.

There are two interesting points of efficiency scores result:

First, Pontianak container terminal is scored as efficient terminal. Pontianak is small container terminal and serves small ships.

Second, TPS is noted as inefficient terminal under DEA-CRS although it is scored efficient under DEA-VRS. The result is surprising as TPS container terminal is second biggest container terminal, serves big ships and located at high growth regional economic, Surabaya.

Scale Efficiency

Many studies have decomposed the technical efficiency scores obtained from a CRS DEA into two components, one due to scale inefficiency and one due to 'pure' technical inefficiency. Efficient score under DEA-VRS could be viewed as 'pure' technically efficient although it is not true enough. This may be done by conducting both CRS and VRS DEA upon the same data. If there is a difference in the two TE scores for a particular DMU, then this indicates that the DMU has scale inefficiency and that the scale inefficiency can be calculated from the difference between the VRS TE score and the CRS TE scores.

Scale efficiency stem from technical efficiency obtained from both two models, CRS and VRS. If there is a difference between two models then the number of scale efficiency will be below 1 and that indicating that scale inefficiency exists. From result above, it can be seen that all inefficient terminal under DEA-CRS has scale inefficiency of maximum 8%. It means that improving efficiency by influencing its throughput is not hard for these terminals.

Return to Scale

The return to scales of production function indicates what happen to output when all input units are increased proportionally. There are three possibilities. First, an increase inputs increases the total output by proportionate amount. When it happens, the production function displays constant return to scale. In the observation, four efficient ports under both CRS and VRS model show constant return to scale.

Second, an increase in inputs will increase the output level with proportion more than the increase in inputs. This case will show increasing return to scale of the production function. Five terminals are operating in increasing return to scale namely Bitung, Serbaguna, Panjang, Palembang and Belawan container terminal.

Third, an increase in input with certain proportion will increase output with proportion less than increase proportion of input. The case will show decreasing return to scale of the production function. Three terminals show operating in decreasing return to scale, namely TPS, Semarang and Makassar container terminal.

Slacks

Slacks consist of 2 kind, input slack and output slack. Input slack indicates that input can be reduced without influencing number of output. Output slack indicates that there needs to be an increased to obtain a projected value.

Efficient ports have no slack. It can be understood because they have been seen be able to use their inputs optimally. All inefficient ports have slack, some have one input slack, some have two and some have all input slack. To become efficient firm, these inefficient firms have two tasks, first reduce their slacks and second reduce their inputs.

Both by DEA-CRS and DEA-VRS, inefficient terminals have no output slack but they have more than two inputs slack. From management side input slack can be seen as excess resources.

Peer and Target

DEA Frontier provides peer and target for each inefficient firm. Peer could be defined as an efficiency reference set, or peer group, defined by a (small) subset of efficient unit 'closest' to the unit under evaluation; i.e. with similar mixes of inputs and outputs. For example, the peer of Terminal Serbaguna is MAL container terminal which relatively have the same size.

The interesting point is almost all inefficient container terminals, under CRS model and VRS model, are benchmarked to MAL container terminal and container terminal Pontianak. This is easy to be understood because both MAL and Pontianak use their resources optimally to produce higher output.

'Target' provided by DEA Frontier is an ideal input for inefficient firm to handle its current throughput. Management should focus to discuss the target provided and bring it to the real situation. Not all targets recommended could be implemented and need adjustment. For example, Serbaguna container terminal is recommended to cut its berth from 404 meters to 163 meters. This recommendation is logic because ideally to handle its throughput now it just needs 163 meters length of berth.

4.3 Result Conclusion

Three out of four efficient container terminals as pointed out by scale efficiency 1 are located in Tanjung Priok port. They are JICT, Koja container terminal and MAL container terminal. Tanjung Priok is a gateway of Jakarta city, the biggest city in Indonesia which and is a place to live for around 15 million people. It seems that efficiency is driven by regional economic activity where ports are located. These ports also handle big ships serving for international trades. Vessel size and cargo exchange (container loaded plus container unloaded per ship) are also an important determinants of terminal efficiency. A greater number of cranes can normally work on a larger vessel, and a larger cargo exchange allows better container selectivity in the vessel hold and result in a lowering of berthing time as a percentage of total service time (Tonzon, 1995).

The surprising result comes from Pontianak container terminal which is noted as efficient terminal and TPS container terminal which cannot achieve efficiency. Pontianak is small river port and serves small ships while TPS container terminal is second biggest container terminal in Indonesia and serves international ships.

All inputs used in the research are fixed cost. Recommendation for reducing it and targets should be achieved seems difficult to be done in the short time. The fixed cost is resulted from long-term planning in the past. Efficiency score could be seen as a picture of anything wrong in business planning in the past and correction should be taken for better strategic port planning in future.

Chapter 5 Result and Analysis

5.1 Introduction

We've had discussed the measurement result in chapter 4 in general. We need to relate the result to reality. This chapter discusses each port regarding the efficiency measurement result. Discussion involves issues in relation with the question below.

- Is efficiency score resulted appropriate for these terminals?
- Does improvement recommendation suit for these terminals?
- Can the research result help management for future improvement?

5.2 Result Discussion for Terminals observed

5.2.1 Jakarta International Container Terminal (JICT)

The terminal is the biggest container terminal in Indonesia owned by PT Pelindo II and Hutchinson Port Holding (HPH). The terminal is located in the port of Tanjung Priok and as a gateway for Jakarta and west Java. Transshipment container handled is just approximately 2 % out of total container throughput.

JICT has two terminals, Container Terminal 1 and Container Terminal 2. Activity is concentrated at Container Terminal 1 which has around 14 meters draft and equipped with panamax and post-panamax cranes. Container Terminal 2 is let to be idle because it has only 9 meter draft which cannot serve international ships and it is equipped with old cranes.

The result of DEA Frontier application for Jakarta International Container Terminal (JICT) could be summarized below.

Table 3: DEA Result for JICT

	DEA-CRS	DEA-VRS
Efficiency Scores	1	1
Slacks	0	0
Peers	JICT	JICT
Target	No	No

Source: own elaboration

JICT is appropriate marked as efficient terminal because of:

- Driven by regional economic activity as located in Jakarta, the biggest city in Indonesia, and place to live for around 15 million people
- Serving big ships so economic scale could be achieved
- Performing 24 working hours

The interesting point is that JICT is scored as efficient terminal even it has idle capacity of Container Terminal 2. It implies that efficiency measured by DEA application does not mean a firm has used its resources effectively.

5.2.2 Container Terminal Surabaya (TPS)

The terminal is the second biggest container terminal in Indonesia owned by Pelindo III and Dubai Port. It is located in Tanjung Perak port, Surabaya, the second largest city in Indonesia, and as a gateway for east Java and Madura. Like with JICT, TPS market is captive so transshipment containers are not so many.

In 2009, TPS container terminal was equipped with 1,450 meters of berth, 10 gantry cranes and handled more than 1.1 million TEUs.

Portrait of efficiency measurement for TPS could be summarized below.

Table 4: DEA result for TPS

	DEA-CRS	DEA-VRS
Efficiency Scores	96%	1
Slacks	Berth:168 m Yard: 3.7 ha	0
Peers	MAL, Lambda 3.291 Pontianak, 1.322	TPS
Target	Berth: 1222 m Cranes : 10 units Yard: 19 ha Employees: 569	No

Source: own elaboration

Under DEA-CRS, TPS is scored 96%, close to efficient and under DEA-VRS, TPS is scored efficient. It can be concluded that TPS operation is technically efficient but because the effect of scale, the overall of TPS has not been efficient. TPS is operating in the decreasing return to scale portion of the production frontier. It could become more productive by decreasing its scale of operation.

Currently, TPS has 1450 meters of berth and 23.7 ha of yard area. It seems to be logic as it has slack of 168 meters of berth if compared with its peer, MAL container terminal. Throughput of MAL container terminal is a quarter of TPS throughput and MAL's berth is only 298 meters. By simple calculation TPS ideally needs berth four times of MAL's berth or around 1200 meters. Compared with Koja container terminal which has throughput a half of TPS container terminal, TPS should have twice of Koja's berth (642 meters) or around 1300 meter. Benchmarking to MAL and Koja container terminal is rationale because ships size arrived at the terminals are similar for international trade.

Slack of 5 ha yard area seems rational if benchmarked to MAL and Pontianak container terminal. But in reality these two terminals have difficulties in container stacking. MAL container terminal has to reduce its dwell time to allow its space sufficient and Pontianak has got many complaints from customer due to limited stacking area. They need more space of yard area for stacking container. If TPS is benchmarked to Koja container terminal which has 21.8 ha yard area, TPS's yard area is sufficient and slack of 3.7 ha yard area is not necessary.

Recommended target of ideal inputs seems to be logic just for the length of berth as explained above. For number of employees, an ideal number is 558 persons that just differs 1 person with current number of employees, i.e. 559 persons. As explained in chapter 4, recommended target to reduce inputs is difficult to be done because inputs used are fixed asset. The facts that the excess input occurred is right. But investment in port sector aim to cover incoming throughput in the future. So it has to be examined when investment was done. If it is a new investment that is normal if excess capacity occurred.

5.2.3 Container Terminal Belawan

The terminal is located in Belawan port, Medan, and serves north Sumatra and Aceh. The terminal is operated and owned by PT Pelindo I. This is the third largest container terminal in Indonesia. The terminal is equipped with 850 meters of berth, 6 gantry cranes and more than 20 ha of yard area. In 2009, it handled around 580 thousands TEUs and has little bit transshipment containers.

Portrait of efficiency measurement for container terminal Belawan is depicted below.

Table 5: DEA result for Belawan

	DEA-CRS	DEA-VRS
Efficiency Scores	88.19%	88.25%
Slacks	Berth: 93 m Employees: 62	Berth : 99.6 m Yard ; 9.6 ha Employees : 63
Peers	JICT, λ = 0.217 MAL, λ = 0.650	JICT λ = 0.192 MAL λ = 0.808
Target	Berth: 657 meter Cranes : 6 units Yard : 18.5 ha Employees: 314	Berth ; 651 m Cranes: 5 units Yard : 17.5 ha Employees: 313

Source: own elaboration

Efficiency score obtained by CRS and VRS is almost same. Scale efficiency obtained is almost close to1. It can be concluded that inefficiency of Belawan container terminal is identified as technically inefficiency. Effect of scale operation is minimal.

The peer of Belawan is MAL and JICT. This apparently seems to be logic because Belawan is a seaport and a gateway of north Sumatra. Ships arrived at Belawan are for international trade so the ships size is almost the same with MAL container terminal.

Belawan has slack for length of berth around 100 meters. It implies that Belawan should have 750 meters length of berth without influencing its output. It seems rational that Belawan should have three berths with 250 meters length of each berth and equipped with 6 container cranes. Slack for number of employees, around 60 employees, seems rationale if benchmarked to Koja container terminal which has similar throughput and similar resources. Koja has 499 employees where Belawan has 583 employees.

Recommendation of DEA to reduce all its input also seems to be logic as compared with JICT and MAL. But it must be careful for implementing the recommendation. Management must observe business plan when the terminal was built. If the differences between business plan and reality are found, action must be taken in order to optimize the asset.

5.2.4 Container Terminal Semarang.

The terminal is located in Tanjung Emas port, Semarang, central Java. The terminal is operated and owned by Pelindo III and as gateway for central java. The terminal is equipped with 513 meters of berth, 5 gantry cranes and around 13.6 ha of yard area. In 2009, it handled around 356 thousand TEUs and most of containers are captive.

Below is a portrait of Semarang container terminal.

Table 6: DEA result for Semarang

	DEA-CRS	DEA-VRS
Efficiency Score	85%	89%
Slack	Cranes : 1 unit Yard : 5.6 ha	Cranes : 1 unit Yard : 1.5 ha
Peers	MAL λ =0.607 Pontianak λ = 1.443	Pontianak λ = 0.451 TPS λ = 0.156 Makassar λ = 0.393
Target	Berth ; 436 m Cranes : 4 units Yard ; 6 ha Employees: 176	Berth: 456 m Cranes: 4 units Yard: 10.6 ha Employees : 184

Source: own elaboration

Efficiency score provided by both CRS and VRS is almost similar, i.e. 85%. It means that Semarang container terminal should reduce 15% of its resources to become efficient. Impact of scale operation is not significant because scale efficiency score is almost close to 1. So inefficiency of Semarang container terminal is identified as technically.

To achieve efficiency, Semarang has to remove its slack, 1 unit gantry crane and 5.6 ha of yard area. The recommendation is logical if benchmarked to its peers, MAL and Pontianak container terminal.

Ideal inputs as recommended by DEA seem rationale. Semarang container terminal seems to have excess resources to produce current output. But it must be checked when investment is done. Port investment is usually aimed to cover throughput growth in the future. So the new port investment would be less efficient.

5.2.5 Container Terminal Makassar

This port is a gateway of east Indonesia, located at Makassar, South Sulawesi. The terminal is operated and owned by Pelindo IV and served loading and unloading container around 370 thousands TEUs in 2009. The terminal is equipped with 850 meters of berth, 5 gantry cranes and around 12.6 ha of yard area.

Efficiency measurement for Makassar container terminal provided by DEA application is depicted below.

Table 7: DEA result for Makassar

	DEA-CRS	DEA-VRS
Efficiency Score	97%	1
Slack	Berth; 347 m Yard ; 7.6 ha	0
Peers	MAL λ = 0.248 Pontianak λ =1.981	Makassar
Target	Berth 480 m Cranes ; 5 units Yard : 4.7 ha Employees: 134	No

Source: own elaboration

Technically Makassar container terminal has been efficient as shown by DEA-VRS. Inefficiency is caused by scale effect. Makassar may be too large and it operates within decreasing return to scale.

Makassar is benchmarked to MAL and Pontianak container terminal. Its throughput is similar to MAL, so its resources seem too large for its throughput. This is very sensible as the terminal has slack around 350 meters of berth and 7.6 ha of yard area. To handle the same throughput MAL will need around 300 meters of berth and 5 ha of yard area. But it must be careful for yard area because both MAL and Pontianak container terminal have many complaints from customers due to limited space of yard area.

An ideal resource as recommended by DEA could be seen that Makassar still has excess resources to handle container growth in the future. This portrait of Makassar is also could be used as input for the review of business plan.

5.2.6 Koja Container Terminal

Koja Container Terminal is a joint venture company between PT Pelindo II and Hutchinson Port Holding (HPH). It has 600 m length of berth and equipped with 6 gantry cranes, 20 RTGs and has 21 ha container yard. In 2009, its throughput achieved 600 thousands TEUs. The terminal is located in port of Tanjung Priok. Like JICT, percentage of transshipment containers through the terminal is very small compared with total throughput.

Table 8: DEA result for Koja container terminal

	DEA-CRS	DEA-VRS
Efficiency Score	1	1
Slack	0	0
Peers	Koja	Koja
Target	No	No

Source: own elaboration

Both using DEA-CRS and DEA-VRS, Koja container terminal is marked as efficient port compared with the other ports observed. Koja seems to have reached its maximum capacity. Koja has limited land for development. So to handle throughput growth, additional container cranes need to be implemented.

5.2.7 Container Terminal Panjang

The terminal is a gateway for province of Lampung and operated by Pelindo II. This is a small container terminal which handled approximately 100 thousands TEUs in 2009. The terminal has 401 meters of berth with 2 berths and equipped with 2 gantry cranes, 6 RTGs and 5 ha container yard.

The DEA result for efficiency measurement of Panjang container terminal is depicted in the table below.

Table 9: DEA result for Panjang

	DEA-CRS	DEA-VRS
Efficiency score	92%	1
Slack	Berth : 225 m Cranes : 0 Yard ; 3.5 ha	0
Peers	Pontianak λ =0.710	Panjang
Target	Berth : 146 m Cranes : 2 units Yard : 1.2 ha Employees:35	No

Source: own elaboration

Inefficiency of Panjang container terminal is caused by scale effect. Technically Panjang has been deemed efficient as presented by DEA-VRS.

From the picture above, it can be concluded that Panjang has excess capacity as pointed out by its slack, 200 meters of berth and 3.5 ha of yard area, and its target. But we look from operational side, excess capacity of Panjang container terminal is minimal requirement for Panjang as gateway of Lampung province. Ships arrived at Panjang usually come every Saturday in order to catch their mother ships schedule in Singapore. Two ships around 180-200 meters usually arrive together and the other day the berth is empty. So, excess capacity is necessary and as minimal requirement for Panjang container terminal to export product of province of Lampung.

5.2.8 Container Terminal Palembang

Port of Palembang is a river port and located at Musi river which is approximately 100 km from sea. The terminal is owned and operated by Pelindo II and as a gateway of South Sumatra province. It is a small container terminal which handled about 84 thousands TEUs in 2009. The terminal has 475 meters of berth and equipped with 1 gantry cranes and 4.7 ha container yard.

Efficiency measurement provided by DEA application for Palembang container terminal is presented in the table below.

Table 10: DEA result for Palembang

	DEA-CRS	DEA-VRS
Efficiency score	97%	1
Peers	MAL λ = 0.120 Pontianak λ = 0.345	Palembang
Slack	Berth : 355 m Yard : 3.37 ha	0
Target	Berth ; 107 m Cranes : 1 Yard ; 1.2 ha Employee : 35	No

Source: own elaboration

DEA application has concluded that inefficiency Palembang container port is caused by scale effect. Efficiency score under DEA-CRS is 97% where under DEA-VRS is efficient. Scale efficiency is also 97% so it means that Palembang is pure technically efficient but not for scale efficiency.

Measurement by DEA-CRS seems appropriate to describe efficiency of Palembang container terminal. Palembang is benchmarked to Pontianak container port. They are both river port and serve small ships around 100-120 meters.

Benchmarked to Pontianak, it seems to be logic that Palembang has slack of 350 meters of berth. Target recommended, that is 106 meters of berth and 1.2 ha of yard area, is reasonable. This portrait of Palembang can be used by management to review business plan.

5.2.9 Container Terminal Pontianak

Pontianak port is also a river port and located at the edge of Kapuas river and about 80 km from the sea. The terminal is owned and operated by Pelindo II and as a gateway of West Kalimantan. It is a small container terminal which handled around 130 thousands TEUs in 2009. The terminal has 205 meters of berth and equipped with 2 gantry cranes.

Efficiency measurement provided by DEA application for Palembang container terminal can be depicted in the table below.

Table 11: DEA result for Pontianak

	DEA-CRS	DEA-VRS
Efficiency score	1	1
Peers	Pontianak	Pontianak
Slack	0	0
Target	No	No

Source: own elaboration

DEA result marks Pontianak as efficient container port. Pontianak is used as peer or benchmarked to other ports observed. The problem faced by Pontianak now is limited land for container stacking because the yard is also used as stuffing and un-stuffing container. That is why Pontianak cannot reduce its dwelling time like MAL container terminal by moving the containers outside. Management should look for land outside for container freight station (CFS) in order to improve the terminal's performance.

5.2.10 Serbaguna Container Terminal

The terminal is located in Tanjung priok port and operated and owned by Multi Terminal Indonesia (MTI), a subsidiary company of Pelindo II. The terminal has 404 meters of berth and equipped with 4 gantry cranes and 6 ha of yard area. In 2009, the terminal served around 158 thousands TEUs.

Table below presents efficiency measurement for Serbaguna container terminal provided by DEA Frontier version.

Table 12: DEA result for Serbaguna container terminal

	DEA-CRS	DEA-VRS
Efficiency score	53.7%	54 %
Peers	MAL λ = 0.153 Pontianak λ = 0.836	MAL λ = 0.143 Pontianak λ = 0.857
Slack	Cranes : 0 Yard : 1 ha	Cranes : 0 Yard : 1 ha Employees : 0
Target	Berth : 217 m Cranes : 2 units Yard : 2.2 ha Employees : 64	Berth : 218 m Cranes : 2 units Yard : 2.2 ha Employees : 63

Source: own elaboration

DEA can well describe the terminal condition. It was built in 1999 and until now it does not operate efficiently. Technical efficiency score, both using DEA-CRS and DEA-VRS is just around 54% and without scale effect.

Slack and target recommended seem reasonable and can be used by management as a warning that the terminal is inefficient and need to be managed well.

5.2.11 MAL Container Terminal

The terminal is located at Tanjung priok port and operated by PT. Mustika Alam Lestari (MAL), fully private company. It served around 300 thousands TEUs in 2009. The terminal has 2 berths and has length approximately 298 meters. It is equipped with 2 gantry cranes, 6 RTGs and has 5 ha container yards. The type of cooperation between Pelindo and MAL is BOT, build operate and transfer. Table below presents efficiency measurement for MAL container terminal provided by DEA application.

Table 13: DEA result for MAL container terminal

	DEA-CRS	DEA-VRS
Efficiency Score	1	1
Peers	MAL	MAL
Slack	0	0
Targets	No	No

Source: own elaboration

This terminal is an example of efficient terminal. It was built about five years ago and now it can operate efficiently. This terminal is used as a benchmark for other terminals observed. The limited yard area is also problem for management but it can be solved by moving the container outside.

5.2.12 Container Terminal Bitung

Bitung is located at north Sulawesi, 45 km from Manado, and as gateway for Sulawesi and Maluku. Bitung container terminal was first operated at 2005. Average container growth is very fantastic, around 50% per year. When first operated in 2005, Bitung served 17,530 TEUs and in 2009 Bitung served 84,926 TEUs. The high container growth has insisted management to develop additional facilities.

Bitung has 292 meters of berth and equipped with 2 gantry cranes, 4 RTGs and 3 ha of yard area. In 2009 the terminal served around 150 thousands TEUs. Table below presents efficiency measurement for Bitung container terminal.

Table 14: DEA result for Bitung

	DEA-CRS	DEA-VRS
Efficiency score	94.6%	100%
Peers	MAL λ = 0.153 Pontianak λ = 0.767	Bitung
Slack	Berth : 3.9 m Yard ; 0.8 ha	No
Target	Berth : 203 m Cranes : 2 Yard : 2.1 ha Employee : 61	Berth : 218 m Cranes : 2 units Yard : 3.1 ha Employee : 64

Source: own elaboration

Bitung is technically efficient, measured by DEA-VRS. Inefficiency of Bitung container terminal is due to scale effect with scale efficiency is around 95%.

It should be careful to interpret slack and inefficiency of Bitung container terminal. In 2009, Bitung developed 100 meters of berth to increase its capacity. It is why Bitung become inefficient. Accordingly, in respect of excess capacity Bitung should be viewed as to fulfill high container growth in future.

Chapter 6 Conclusion and Recommendation

6.1 Conclusion

The main objective of the thesis is to find out efficiency of container terminals in Indonesia. The information will be useful both for government and operators of terminals in order to make future improvement. The analysis tools used are DEA-CRS and DEA-VRS. The reason of using this two analysis tools is to separate efficiency in two types, technically efficiency and scale efficiency.

Number of container terminals observed is 12 terminals which have similar characteristics such as captive market, equipped with similar technology and having the same wage rate. Two out of 12 terminals are river ports which handle small size of ships.

Through this study it can be known that efficiency problems of container terminals in Indonesia are as follows:

First, as result of DEA-CRS and DEA-VRS model, 4 out of 12 terminals are expressed as efficient container terminals. They are JICT, Koja container terminal, MAL container terminal which are located in the same place, Jakarta, and Pontianak container terminal. As predicted before, JICT, Koja and MAL container terminal would be efficient terminals because these terminals serve big ships and located at highest regional economic growth, Jakarta. The result is surprising when it shows that Pontianak is also scored as efficient container terminal. Unlike other terminals, Pontianak is a river port which serves small ship range 100-120 meters and has the fewest throughputs among the other efficient terminals. The result is also surprising because TPS container terminal, the second biggest container terminal in Indonesia, scored as inefficient terminal. It has excess capacity of quay length and yard area.

Second, four terminals are technically efficient as showed by DEA-VRS. They are Palembang, Panjang, TPS, Bitung and Makassar container terminal. These terminals become inefficient, as shown by DEA-CRS, due to the scale effect. Some terminals may be too small in its scale of operation which falls within the increasing return to scale and some terminals may be too large and it may operate within decreasing returns to scale. Theoretically, efficiency of these terminals could be improved by changing their scale of operations.

The facts as shown by DEA result, these terminals have excess inputs especially on length of berth and yard area. The result makes sense if they are benchmarked to MAL and Pontianak container terminals.

Third, three terminals are inefficient as resulting from both DEA-CRS and DEA-VRS. They are Serbaguna, Belawan and Semarang container terminals. Theoretically, to become efficient terminal, these terminals should remove their slacks and reduce their inputs 6% to 47%. The most inefficient terminal is Serbaguna container terminal which is operated by Multi Terminal Indonesia (MTI).

6.2 Limitation of Information provided

DEA has provided information of efficiency of container terminal in Indonesia. However one should be careful when using the information.

First, the term of efficiency used in DEA does not mean that terminal has already used its resources efficiently. In this case, JICT as efficient terminal still has idle capacity of Container Terminal 1. The term of efficiency used in DEA means the terminal operates at the production frontier and inefficiency means the terminal operates below production frontier. Production frontier is determined by using linear programming technique and could be seen as best practice of terminals observed.

Information of slack and target provided should be examined carefully. Inputs used are fixed asset that cannot be increased or reduced in short term. The facts that inefficient terminals have slack and excess capacity in producing current output are right. But management cannot remove the slack and reduce inputs in short time because of fixed asset characteristic. In Indonesia, employee could be viewed as fixed asset because it cannot be reduced in short time.

Efficiency should be seen in accordance with the long term planning. Port investment is aimed to capture future container growth. Accordingly, new investment is certainly not efficient, like Bitung container terminal. A terminal could be judged as failed or inefficient terminal if it is operating not as expected. In this case, Serbaguna container terminal can be used as an example.

6.3 Recommendation

Ranking of container terminals efficiency is a portrait of container terminal management in Indonesia. As a portrait, the information can be used as input for reviewing long term business planning. Port investment is a product of medium and long-term port strategic planning.

Slack and target recommendation presents excess resources terminal uses. But because of inputs used is fixed assets, management cannot remove or reduce it in the short time. Excess resources maybe caused by two things: first because it is a new investment and the second due to improper business planning. For example Bitung has excess capacity which is in order to capture future container growth and Serbaguna container terminal is due to improper business planning. Therefore further research should be performed to relate inefficiency with time of investment.

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Appendices

APPENDIX-1

Company	Length of Berth (M)				Number of Cranes (Unit)				Yard Area (M2)				Number of Employee				Throughput (TEUs)			
	2007	2008	2009	Average	2007	2008	2009	average	2007	2008	2009	average	2007	2008	2009	averag	2007	2008	2009	average
JICT	2.130	2.130	2.130	2.130	14	13	17	14,67	700.000	700.000	700.000	700.000	1.010	1.020	959	996	1.821.292	1.985.781	1.671.246	1.826.106
Koja	642	642	642	642	6	6	6	6,00	218.000	218.000	218.000	218.000	498	497	490	495	704.961	704.701	619.811	676.491
Serbaguna	404	404	404	404	4	4	4	4,00	60.000	60.000	60.000	60.000	119	119	119	119	135.050	175.475	164.060	158.195
MAL	298	298	298	298	2	2	3	2,33	50.000	50.000	50.000	50.000	150	150	150	150	274.018	300.824	289.067	287.970
Panjang	401	401	401	401	2	2	2	2,00	51.000	51.000	51.000	51.000	42	36	35	38	79.767	106.935	104.175	96.959
Palembang	475	475	475	475	1	1	1	1,00	47.100	47.100	47.100	47.100	36	35	37	36	82.546	78.469	84.403	81.806
Pontianak	205	205	205	205	2	2	2	2,00	17.320	17.320	17.320	17.320	59	45	43	49	143.443	132.732	133.419	136.531
Belawan	850	850	850	850	4	6	6	5,33	209.308	209.308	209.308	209.308	341	384	553	426	581.378	590.307	580.210	583.965
TPS	1.450	1.450	1.450	1.450	10	11	10	10,33	254.127	254.127	202.501	236.918	618	603	559	593	1.113.478	1.152.999	1.117.554	1.128.010
Semarang	513	513	513	513	7	5	5	5,67	84.500	138.100	187.167	136.589	193	216	213	207	385.095	373.644	356.461	371.733
Makassar	850	850	850	850	4	5	5	4,67	126.400	126.400	126.400	126.400	138	138	138	138	302.023	353.247	370.532	341.934
Bitung	182	182	292	219	2	2	2	2,00	30.960	30.960	30.960	30.960	64	64	64	64	117.117	134.756	148.754	148.754

2