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Research Article

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An Evaluation Seaport Terminal Efficiency Using Data Envelopment Analysis

M. Kasypi[1], N. Hasnaa Kamilah Dalim[1], Wan Muhamad Amir Wan Ahmad[2], Azlida Aleng[3], Rudiah Hanafiah[1]

[1]School of Maritime Business and Management, Universiti Malaysia Terengganu, Malaysia
[2]Department of Dentistry, Universiti Sains Malaysia, Malaysia
[3]School of Informatics and Applied Mathematics, Universiti Malaysia Terengganu

Abstract Ever since establishment of container box, demands for expansions of container terminals have increase tremendously. In addition to larger container vessels available in the industry, significant throughputs need to cater for terminals survival. Apart of that, terminals efficiency and productivity becomes an indicator to attract liners to berth. Concerned with these, this research aims at evaluating efficiency of container terminals in Malaysia. As privileged of being maritime nation, competition with other terminals in the region as a boost factor to accelerate resources available. Therefore, Data Envelopment Analysis (DEA) as an alternative technique is used to analyse results of 2005-2015 of data from respective and reliable resources. Based on efficiency results of constant and variable return to scale, relatively terminals are able to utilise its resources with relative efficient to its results. It reflects that efficiency does not relate to small, moderate or big terminals. These significant results provide an idea to port managers and decision makers to aware of utilisation of terminals are optimum. Analysis of port data allows port users to compare for efficiency and productivity among port operators. The results are necessary for pre and post terminal planning and operation.

Keywords Efficiency, Container Terminal, Data Envelopment Analysis

1. Introduction

Port is defined as a boundary between land and sea or a linkage of waterway to facilitate and serve to commercial ships and cargoes, as well as related to the multimodal, distribution and logistics activities [3]. Similar to other countries, Malaysia ports are the place where ships load and unload the cargoes. The country's ports have a crucial role in the overall pattern of trade and transport, providing a connection between the shipping service and the inland transport system. Malaysian ports today, own world-class facilities of significant act point. This point interfaces with other modes of transport also called as multimodal such as road, rail, river and air. In maritime sector, transferring products via vessels is an important element as it contributes to the international trade. Therefore, global trade via seaport contributes cargoes significantly, and the cargoes dominant by the container. The most container ports are located along the busiest shipping lane as container terminal is the main part of transportation for throughput handled. For example Port of Hong Kong, Port of Shenzhen, Port of Singapore and others. Hsu [11] states it is a focal point where the container can be transhipped from one mode to another. Seaport compete each others for the throughput, container terminal needs to cater demands in a short time at a low cost with efficient operation, especially on main route sea containers. Figure 1 shows a distribution of whole ports in Malaysia.

Figure 1: Ports Distribution in Malaysia

2. Literature Review

Historically, the first regular sea container service has started around 1961 with involved globally between US East Coast and points in Caribbean, Central South America. Nowadays, over 60% of the worlds' deep-sea general cargo is transported via containers. At a terminal, there are variety of infra and superstructures to transfer containers from vessel or barge to other modes and vice versa [9]. As every container terminal is a complex system that functions efficiently when its layout is designed in such a way that the loading and discharging of vessels properly. A part from that, container terminals mainly segregate by five areas, those are berth side, quayside, transport area, yard and gate [5].

2.1. Efficiency in Container Terminal

Efficiency is the ratio of actual output attained to standard input expected. It is also said significant element in the production process; could be measured by parametric approaches applying econometric tools or non-parametric in regards to mathematical programming theory [4]. Measuring the efficiency, the actual attained or realized value of the objective function is compared against what is attainable at the frontier [16]. Efficiency is the main issue in contemporary port economics, on the grounds of a port's strategic position in linking variety of countries in a globalized world, also connecting different parts inside the country [10]. Hence, port efficiency analyses the ability of a port to obtain the maximum output under a given amount of inputs or through the use of the minimum amount of inputs under a given amount of outputs specifically it depends either input or output.

There are varieties of equipment with their own function in employed to tranship containers from vessels to other modes and vice versa. Every container terminal was designed systematically to serve efficiently in loading and discharging vessels. Container terminals are mainly segregated by five areas, those are berth side, quayside, transport area, yard and gate [5, 12-13]. Rodseth *et al.* [18] said terminal port provided large stacking area, gantry crane works for loading and unloading the container to the ship (vice versa), and several facilities and equipment for moving the containers to transfer to other modes. Another option is for the container handling to transport them to the shipside on a rolling platform using tractors or mobile platforms.

3. Methodology on Efficiency Technique: Data Envelopment Analysis:

DEA is a non- parametric technique, measure technological efficiency by relating various inputs to outputs. DEA has many benefits over techniques, such as performance ratio and regression analysis, which could be said an appropriate tool for management in variety of field or industry. In addition, referred the main advantage of DEA which makes its transference to the complex port industry even its ability to include multiple input or output criteria. Roll & Hayuth [19] as pioneers, DEA has been applied widely in analyzing container port efficiency and nowadays perform as main role in container port performance evaluation.

Efficiency is derived and part of productivity, where it is a ratio of actual output attained to standard output expected [20]. Mali [15] express together the terms productivity, effectiveness and efficiency as follows:

$$\text{Productivity index} = \frac{\text{output obtained}}{\text{input expected}} = \frac{\text{performance achieved}}{\text{resources consumed}} = \frac{\text{effectiveness}}{\text{efficiency}} \quad (1\text{-}0)$$

Therefore, Sumanth [20] and Ramanathan [17] express efficiency as follow:

$$Efficiency = \frac{Output}{Input} \quad (2\text{-}0)$$

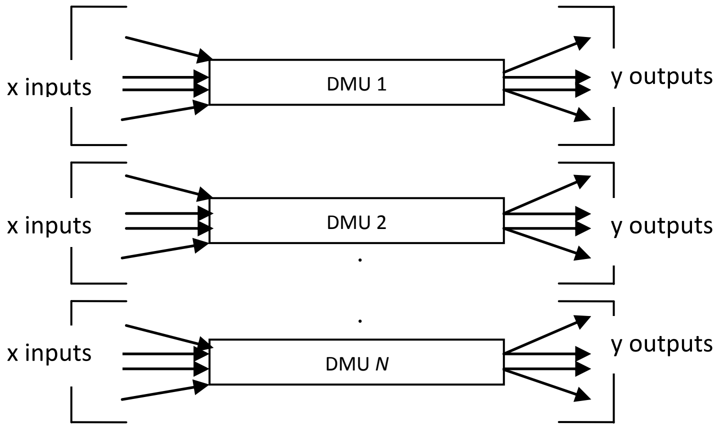

Figure 2: DMU and Homogeneous units

The (2-0) equation is applicable for evaluation of simple data. The entity of output and input are diverse significantly. Therefore, equation (2-0) is not suitable for complex relationship between outputs and inputs. The weight cost approach is the solution for complexities of outputs and inputs as follows:

$$Efficiency = \frac{\sum weighted\ of\ outputs}{\sum weighted\ of\ inputs} \quad (3\text{-}0)$$

By assuming all weights are uniform, mathematically equation is expressed as follows:

$$Efficiency = \frac{\sum_{r=1}^{n} u_r y_r}{\sum_{s=1}^{n} v_s x_s} \quad (4\text{-}0)$$

Where;

y_r = quantity of output r

u_r = weight attached to output r

x_s = quantity of input s

v_s = weight attached to input s

An efficient is denote = 1, therefore, to classify unit of efficiency is set as $0 < \text{Efficiency} \leq 1$.

3.1. Technical Efficiency

Data Envelopment Analysis (DEA), first introduced by Charnes, Cooper and Rhodes (CCR) in 1978 [6], extended by Farrel (1957) idea of estimating technical efficiency with respect to a production frontier. The definition of efficiency is referred from the "Extended Pareto-Koopmans" and "Relative Efficiency" The CCR is able to calculate the relative technical efficiency of similar Decision Making Units (DMU) through the analysis, with the constant returns to scale basis. This is achieved by constructing the ratio of a weighted sum of outputs to a weighted sum of inputs, where the weights for both the inputs and outputs are selected so that the relative efficiencies of the DMUs are maximized with the constraint that no DMU can have a relative efficiency score greater than one. On the other hand, the DEA-BCC model [2] extend from DEA-CCR by assuming variable returns to scale where performance is bounded by a piecewise linear frontier. There are other DEA models in the literature, but DEA-CCR and DEA-BCC are the most commonly used models.

Since the CCR (1978), the development has introduced the BCC model that is Banker, Charnes and Cooper in 1984 [2]. The BCC model relaxes the convexity constraint imposed in the CCR model which allows for the efficiency measurement of DMUs on a variable returns to scale basis. The BCC model results in an aggregate measure of technical and scale efficiency, the CCR model is only capable of measuring technical efficiency. This allows for the separation of the two efficiency measures.

The scale efficiency measurement indicates whether a DMU is operating at the most efficient scale, while technical efficiency is a measure of how well the DMU is allocating its resources to maximize its output generation. It is important to note that the BCC model is both scale and translation invariant, while the CCR model is only scale variant. The development of the Additive model, which involves reduction of inputs with a simultaneous increase in outputs, and Multiplicative models note worthy advances which, along with further explanations of the DEA technique and its extensions, are outlined in literature [1, 7-8, 14]. Since the first application of DEA for measuring the efficiency of business student to schools Charnes *et al* [6] the technique has been applied in over 50 industries i.e., healthcare, transportation, hotel, education, computer industry etc.

DEA is useful mathematical programming technique for evaluating efficiency which measured efficiency of Decision Making Unit (DMU) with multiple inputs or multiple outputs. Based on Vanessa *et al* (2014), there are two classical DEA models commonly applied; firstly, the model of constant returns to scale (CRS or CCR) pioneered by Charnes, Cooper and Rhodes in 1978 [6]. Secondly, the model of variables returns to scale (VRS or BCC) coined by Bankers, Charnes and Cooper in 1984 [2].

Indices	j	-	DMUs, $j = 1,\dots,n$
	r	-	Output, $r = 1,\dots,t$
	i	-	Input, $i = 1,\dots,m$
Data	y_{rj}	-	the value of the rth output of the jth DMU
	x_{ij}	-	the value of the ith input of the jth DMU
	ε	-	a small positive number
Variables	$s_{i,}{}^{\delta}$	-	Slacks corresponding to input$i$, output r respectively (≥ 0)
	λ_j	-	Weight of DMU_j in the facet for the evaluated DMU (≥ 0)
	$\mu_r v_i$	-	Virtual multipliers for output r, inpu ti respectively (≥ 0)
	h_k	-	Relative efficiency of DMU_k

Equation for efficiency

CCR

$$\max \theta_k$$

$$\theta_k y_{jk} - \sum_{k=1}^{k} \lambda_k y_{jk} \leq 0 \tag{5-0}$$

$$\sum_{k=1}^{k} \lambda_k x_{ik} \geq x_{ik}$$

$$\lambda_k \geq 0$$

BCC constraint added

$$\lambda_k = 1 \tag{6-0}$$

4. Analysis and Discussion

The research aims to optimize function of container terminal in utilizing allocated resources. Therefore, the resources selected closely to the main activities in handling container terminal. Table 2 illustrates the descriptive statistics of variables inputs and output afore mentioned. The descriptive statistics analysis is represented through maximum, minimum, average and standard derivation. The maximum and minimum of TTA are 2,700,000 m² and 27,283 m² respectively, while average and standard derivation for TTA are 1,001,743.13 m² and 765,320.36 m² respectively. Then, the average and standard deviation of main equipment; QC, RTG and PM are 22.14, 61.80 and 155.76 and 16.13, 54.09 and 139.95 respectively. However, maximum and minimum output variable which is container throughput are 9, 053, 397.00 and 119, 067.00 respectively. Table 3 depicts descriptive analysis for CCR and BCC.

Table 2: Summary of Descriptive Variables

Variables	Max	Min	Average	SD
TTA	2700000	27283	1279214	875152.575
DFT	19	11.2	15.033	2.942
BL	5040	759	3226.833	1602.933
QC	56	5	28.167	21.146
RTG	174	6	81.667	65.987
SC	20	0	3.833	7.312
RS	27	0	6.333	9.393
EH	20	0	4.167	7.312
FL	9	0	1.5	3.354
TC	695	19	259	242.279
PM	460	7	201	180.183
YSC	961300	7104	252783	327739.389
TTP	9053397	140959	3809045	3678246.793

Table 3: Descriptive Analysis of CCR and BCC

Descriptive	CCR	BCC
Average	0.9305	0.9584
SD	0.0852	0.0582
Maximum	1.0000	1.0000
Minimum	0.6667	0.7407
No. of efficient DMUs	27	32
No. of inefficient DMUs	39	34

4.1. The Efficiency of Container Terminal's Resources in Peninsular Malaysia:

Having measured for six (6) container terminals for 2005-2015, there are 66 DMUs investigated in this research. Figure 3 shows inter panel data container terminal efficiency, the volatility of efficiency data for the past 10 years are shown. For a constant return to scale, it portrays these 27 DMUs are able to utilize all resources to achieve for efficient =1. There are another 39 DMUs are inefficient (<1), caused by internal or external factors, for example, EPP2009, AW2011, BN2012, FK2008 etc.

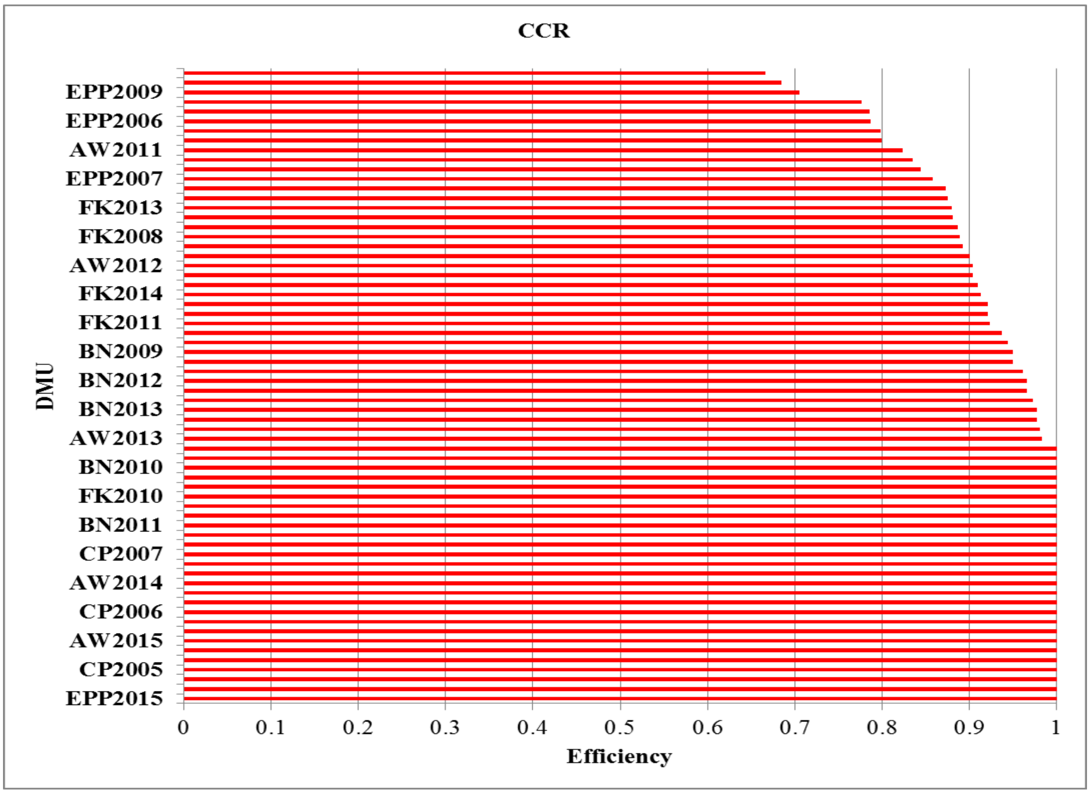

Figure 3: Score DEA CCR-Output Oriented of DMUs

Table 4 below summarizes from output-oriented of CCR overall outcomes. The average score through CCR-Output Oriented is 0.9305 shows close to 1 and standard deviation is 0.0852. FK2005 is the utmost inefficient container terminal with the score of 0.6667.

Table 4: Descriptive Variables of DEA CCR-Output Oriented

	CCR
Average	0.9305
SD	0.0852
Maximum	1.0000
Minimum	0.6667
No. of efficient DMUs	27
No. of inefficient DMUs	39

Figure 4 shows variable return to scale panel data for output oriented of DEA BCC. Variable return to scale is added constraint of return to scale. Results depict 32 DMUs are efficient where utilization those of resources at optimum level. There are another 34 inefficient DMUs as utilization of resources <1. The lowest inefficient DMU is EPP2008 with the score of 0.7407.

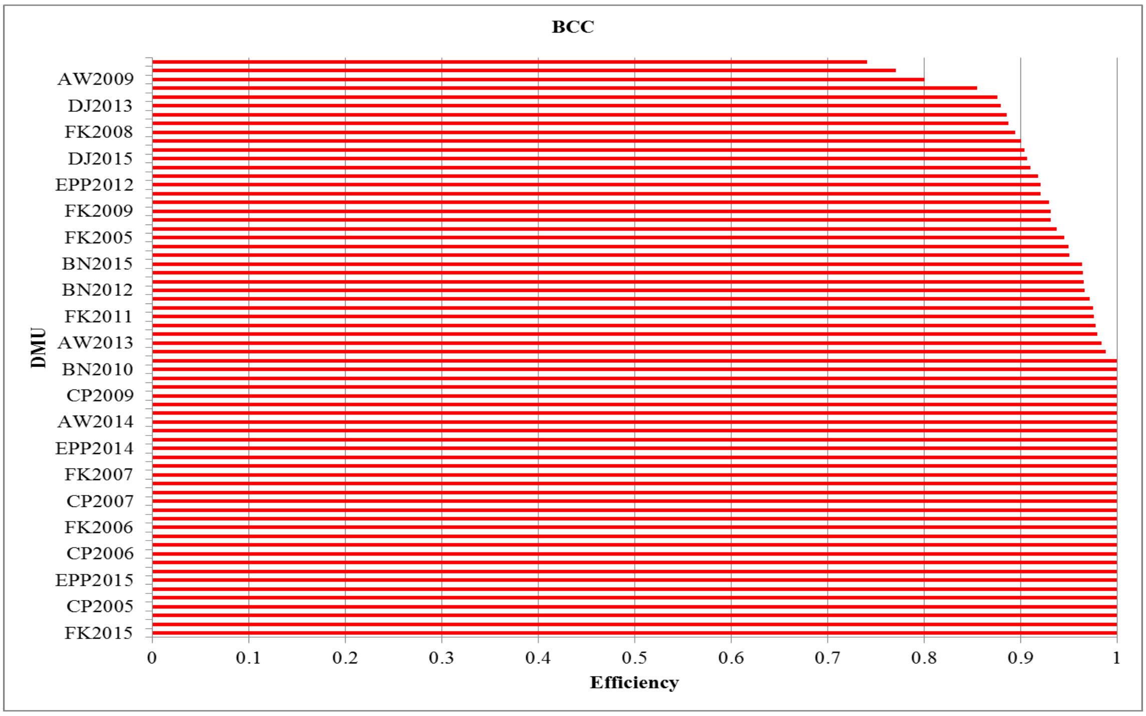

Figure 4: BCC-Output Oriented Efficiency

Table 5 below exhibits summary of DEA BCCO, where the overall mean at 0.9584 with standard deviation spread out over a large range of value 0.0582.

Table 5: Descriptive Variables of DEA-BCCO

	BCC
Average	0.9584
SD	0.0582
Maximum	1.0000
Minimum	0.7407
No. of efficient DMUs	32
No. of inefficient DMUs	34

4.2. Variable Return to Scale DEA BCC

BCC also exhibits projected return to scale outcome. The results show clearly in Table 6.0 where number of constant returns to scale for efficient terminal is 27 and 16 more projected to be constant. Increase return to scale is 5 and is projected to increase up to 18. In order for DMU projected to be efficient, another 27% utilization of resources is needed to achieve score efficiency equals to 1, the availability of resources has to accomplish the maximum score. So that, investment of port facilities such as expansion of infrastructure, upgrading facilities (equipment) are worth to be done, as ports are influenced to increase their efficiency. However, those 27 are efficient under a constant return to scale, have to recover in the managerial side to balance in operational side.

Table 6: Projected Variable BCC Model

RTS	Efficient	Projected	Total
Increase Return to Scale	5	18	23
Constant Return to Scale	27	16	43
Decrease Return to Scale	0	0	0

5. Conclusion

The objective of this research is measure efficiency of container terminal in Peninsular Malaysia. It is crucial to maintain the significant role as nation gateway around this region. On top of that, level of efficiency able to attract liners to berth at container terminals in Peninsular Malaysia. Overall results represent that EPP2015, AW2005, BN2005, CP2005, and DJ2005 achieved efficient score which is equal to 1. Therefore, to maintain efficiency and productivity it is necessary to have good port planning. From that, container terminals can have better forecasting result in future.

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