Efficiency of Operations in Container Terminals: A Frontier Method

Kasypi Mokhtar[1]   Muhammad Zaly Shah[2]

1. Department of Maritime Management, Faculty of Maritime Studies and Marine Science
Universiti Malaysia Terengganu, Malaysia Email: m.kasypi@yahoo.com

2. Department of Urban and Regional Planning, Faculty of Built Environment
Universiti Teknologi Malaysia Email: zaly@live.utm.my

Abstract

Nowadays transporting cargo via containers are significant for every shipment. The movement of container involves multi modes to reach destination. In Malaysia, efficient transport networking systems are catalyst for container terminal in providing excellent services to their client. The paper focuses on the metamorphosis of the terminal efficiency and container movements at 6 major container terminals in Peninsular Malaysia. The aim is to analyse the efficiency of container terminals that contributes significant economic development in Peninsular Malaysia. Non parametric approach under frontier method is used to analyse panel data from 2003 to 2010 in relation with container terminal equipments and throughput. Result of the analysis shows no significant relationship between container terminal size and efficiency. Thus, efficiency is determined from allocation of resources efficiently by terminal operators and not by size of terminals.

Keywords: Technical efficiency, Container terminal, Data envelopment analysis, Terminal productivity, Transportation

1. Introduction

Since the invention of container by Malcom Mclean late 1950s, and the first international shipment in 1966, the shipments of goods have changed drastically (Levinson, 2006). In addition, containerisation is applied to all modes of transport such as rail, container vessel and haulage. The handling process of moving of goods continuously improved, and it has benefited to all parties. Containerisation and the development of intermodal transports system have had a profound effect on the shipping industry, its structure, management and operation. The movement of goods in a single container by more than one mode of transportation was an important development in the transportation industry and all the elements involved for the international and domestic trade. Classically, the terms 'Through Transport', 'Combined transport', 'Intermodal transport', and 'Multimodal transport' are preferable for movement of goods. It started from the point of origin to point of destination. These four terms have very similar meaning, where the movements of goods are involved with more than one mode to ship the cargo (UNCTAD, 1993; 2001). Multimodality or intermodality has given tremendous impact to the transport industry (Hayuth, 1987; Hariharan, 2002; Levinson, 2006).

The study covers 6 major container terminals in Peninsular Malaysia. The non parameter technique under frontier method called as data envelopment analysis (DEA) is used to analyse panel data from 2003 to 2010. The first section starts with introduction and follows with theoretical perspective on transportation systems in section 2. Under section 3, discussion on the efficiency technique and DEA model is developed for the research. Section 4 discusses DEA that has been applied at container terminal. Furthermore, the model is apply for this research to analyse the panel data. Section 5 represents results and discussion on the analysis from DEA-CCR and DEA-BCC output-oriented.In Section 6 represents conclusion on the research.

2. Theoretical Perspective: Containerisation and Transportation Network

Back in 1955, delivery process has been changed when Malcolm Mclean introduced standardised container box (UNCTAD, 1993; 2001; Levinson, 2006).   The first shipment by using container took place in Newark, New Jersey USA where shipment of cargoes to Puerto Rico of a Sea-Land vessel.   However, Sea-Land international maiden only happened in 1966 because of confrontations with shipping lines (Talley, 2000; Levinson, 2006). First international called for Sea-Land was to Rotterdam, and since that time; the new era of shipping industry has emerged with the international trade via International Organisation for Standardisation (ISO) container.
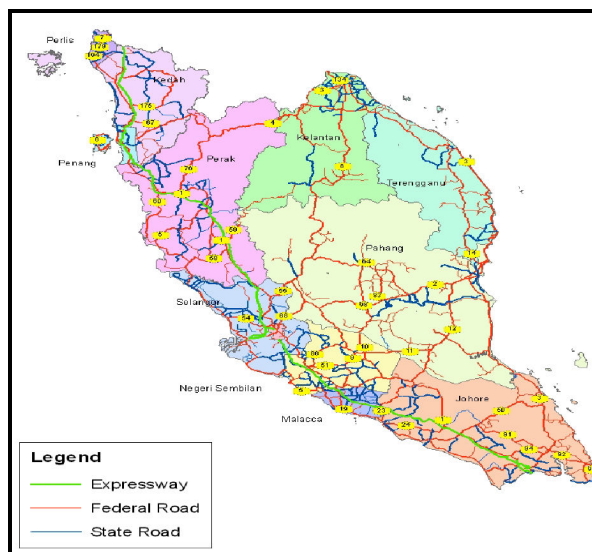

Figure 1. Major Road Network in Peninsular Malaysia (PWD, 2009)

An efficient and good road networks are main catalyst for movement of good via road (World Bank, 2005). The road networks are accessible throughout Peninsular Malaysia and contribute significant towards state economic development. The accessibility has spurred development of container terminal in Peninsular Malaysia. Its locations are in Penang (Penang Port), Selangor (Westport and Northport), Johor (Johor Port and Tanjung Pelepas Port) and Pahang (Kuantan Port). Hayuth (1987, 1994) emphasis that integrated logistic network is important for movement of container via road. Figure 1 depicts road network in Peninsular Malaysia. The road network consists of expressway, federal and state road. In Peninsular Malaysia, total road network systems are 82144 kilometre (PWD, 2009). The road

breakdowns are 61420 km under state and municipality roads, 18904 km under federal roads and 1820 km are toll highways (PWD, 2009; Levinson and Zhu, 2011).

Figure 2 depicts the impact and transformation from conventional to container on the containerised port system. It was manifested into two impacts which are spatial and organisational. With the introduction of container system, the port process has been changed drastically from the equipments, manpower, port system and port's charges. This transformation has classified terminal more organised even though the process becoming more complex. However, by having an organised structure container terminal operation is able to handle efficiently. Containerisation contributes to a higher efficiency in the development of multimodal transport operations. The focus, now, is more on the organisation of the transport industry and the synchronisation of the integrated logistical system (Hayuth, 1987; Carrese and Tatarelli, 2011). In order to achieve multimodal transport, intensive co-operation and co-ordination among transport modes are essential.

Figure 3 shows the impact of intermodal transport on the containerized port system. During those days, there are two phases of transformation of containerized port system. The first phase of port containerization involved a period of technological change and a massive growth in the spatial dimensions of terminals. For the second phase, its focuses attention on organizational aspects of international transport and the port industry i.e., marketing strategies, participation by ports in the physical distribution of cargo. Thus, in this phase the containerized port system is an integrated transport system
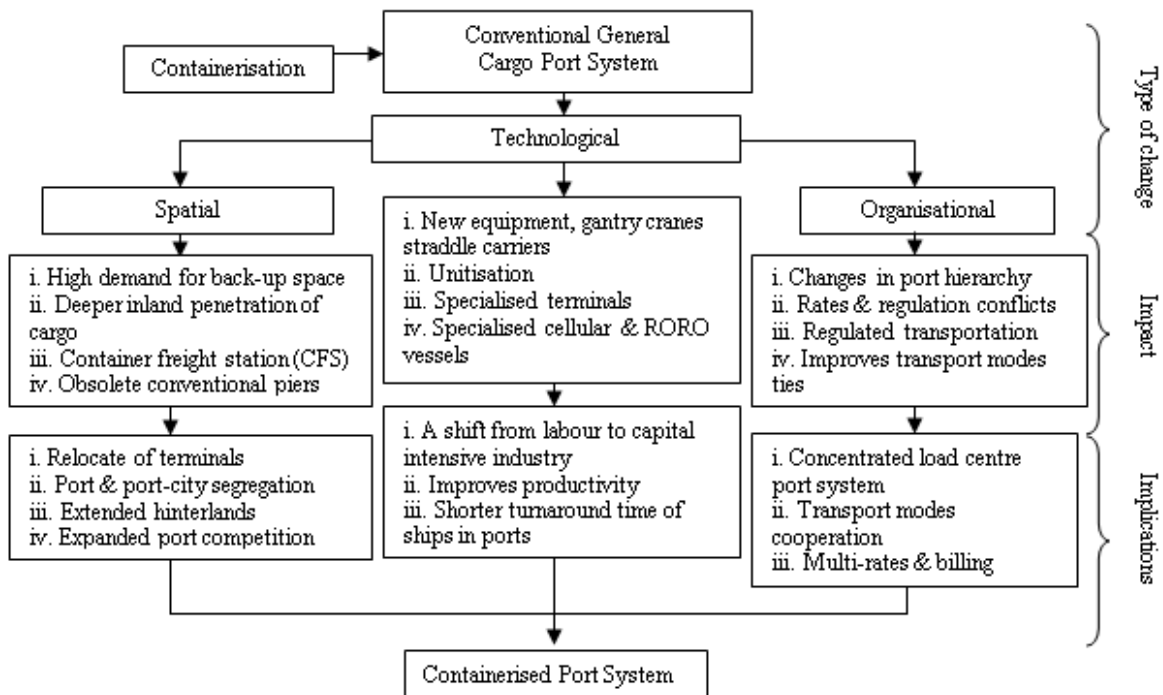
Figure 2. The Impact of Containerisation on the Conventional General Cargo Port System (Hayuth, 1987)
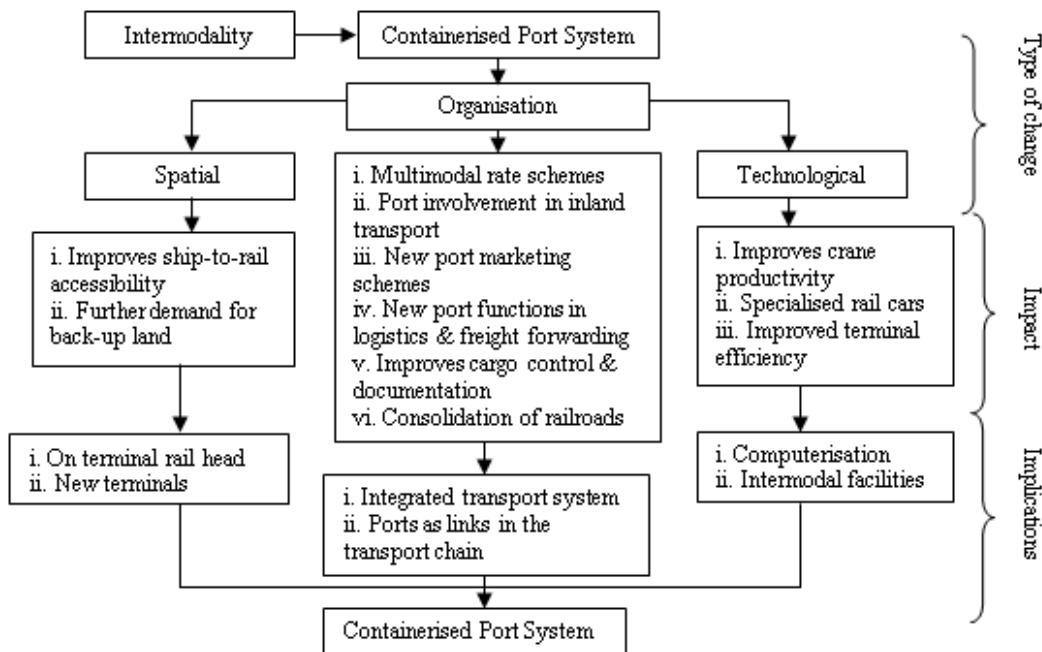

Figure 3. The Impact of Intermodal Transport on the Containerised Port System. (Hayuth, 1987)

*2.1 The Significance Containerisation Towards Transportation Systems*

Container is a loading unit that has the advantage of being used by several modes of transportation i.e., maritime, rail and road. These modes are able to handle container smoothly based on the type of handling equipments. At large, the flexibility of loading unit has improved freight transportation in terms of cost, loading and discharging cargo. Containerisation relates the relationship between freight transportation modes and the increasing burden of standardization. International Standardisation for Organisation (ISO) container refers to 10, 20, 30 and 40 feet long. However for measurement, the reference size container 20 feet long, 8 feet high and 8 feet wide, corresponding to the twenty-foot equivalent units (TEUs). The most common Container is 40 feet long that can be loaded on ship, truck or railcar.

Since the invention of container, the idea to integrate container between different transportation has been made and involve more than one mode. This term called as intermodal, multimodal, combined and through transport. The terms especially intermodal and multi modal transport have become worldwide known. Intermodal or multimodal transports are proven increase supply chain productivity of shipment and performance of distribution of cargo at large. Therefore, the economic distance maritime shipping and rail can be used for the long term, the efficiency of the trucks that provide local distribution.

The Message for transport is seen as a whole, and not as a series of stages, each characterized by individual operations with separate sets of documentation and rates. The emergence of intermodal transportation has brought in part by technology. Techniques for transferring freight from one mode to another have facilitated intermodal transfer. Early examples include piggyback, in which truck trailers are placed on rail cars, and the LASH (lighter aboard ship), where the river barges placed directly on a seagoing ship.

Facility will accommodate containerships, built ships exclusively for the purpose of bringing the former set. Railway, the new facility is also required to handle container traffic as well as specialized railcars. Former Double stacking the railway has double the capacity of rail for freight space with minimal cost increases, thus improving the competitive position of rail in terms of long-haul trucks for delivery. Road transport has also been adapted to containerization, but the minimum requirements of the new trailer can be captured in a container. Intermodal transport changes increased distribution of cargo around the world.

Large integrated transportation carriers provide door to door service through the sequence mode, terminals and distribution centres. Thus, concern, especially with the cost and service level. For customer intermodal transport services, transport and distance appear to be meaningless, but for the intermodal providers routing, cost and frequency of services has played a bigger stake.
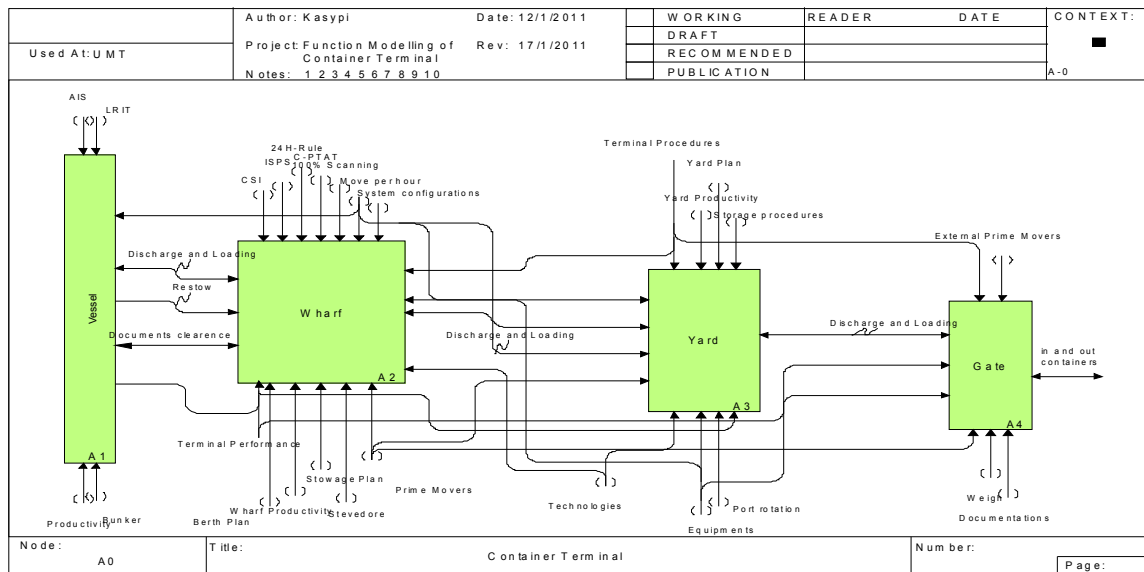
ure 4. IDEF0 Model for Container Terminal (Kasypi and Shah, 2012)

Kasypi and Shah (2012) establish the integration model of container terminal by applying IDEF0 with supply chain. The model integrates component at container terminal in enhancing the operational activity. Figure 4 depicts the IDEF0 model for container terminal.

3. Efficiency Technique: Data Envelopment Analysis

Efficiency is derived and part of productivity, where it is a ratio of actual output attained to standard output expected (Sumanth, 1984). Mali (1978) 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 (1984) and Ramanathan (2003) express efficiency as follow:

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

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:

www.iiste.org

IISTE

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

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

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

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 $0 < Efficiency \leq 1$.

3.1 Technical Efficiency: Data Envelopment Analysis

Data Envelopment Analysis (DEA), first introduced by Charnes, Cooper and Rhodes (CCR) in 1978 (Charnes et al, 1978), extended Farrell's (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 (Banker et al., 1984) 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 (Barnes et al, 1984). 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 (Ali and Seiford, 1993, Charnes et al, 1994a, Charnes et al, 1994b and Lovell, 1993). Since the first application of DEA for measuring the efficiency of business student to schools (Chanrnes et al, 1978) the technique has been applied in over 50 industries i.e., healthcare, transportation, hotel, education, computer industry etc.

3.1.2 Model Development

The model is developed from the extension of the ratio technique used in traditional efficiency approaches. The measurement is obtained from DMU as the maximum of a ratio weighted output to weighted input. The numbers of DMUs are not determined outputs and inputs, however, larger DMUs are able to capture higher performance. This would determine the efficiency frontier (Golany and Roll, 1989). In addition, the number of DMUs should be at least twice the number of inputs and outputs (Golany and Roll, 1989).

The parameters and variables are needed in developing the model. Therefore, the model is based on the following parameters and variables:

N = number of DMU $\{j = 1,2,...n\}$

y = number of outputs $\{y = 1,2,...R\}$

x = number of inputs $\{x = 1,2,...S\}$

y_i = Quantity of output r^{th} of output of jth DMU

x_i = Quantity of input s^{th} of input of jth DMU

u_r = weight of rth output

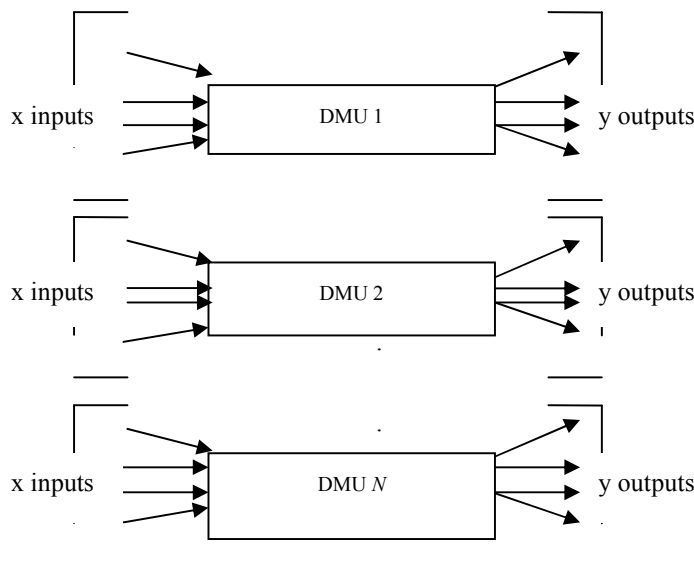v_s = weight of sth input

Figure 5: DMU and Homogeneous units

Golany and Roll (1989) describe that homogenous unit is important in choosing DMUs to be compared and identifying the factors affecting DMUs. Therefore, homogenous group of units need to perform similar task and objectives, under same set of market conditions and the factors (inputs and outputs). Figure 5 depicts the DMU and homogeneous units. This concept is using linear programming (LP) formulation to compare the relative efficiency of a set of decision making units (DMUs). Farrell (1957) has developed similar approach to compare the relative efficiency of a cross-section sample of agricultural farms.

The efficiency measures under constant returns to scale (CRS) are obtained by N linear programming problems under Charnes et al. 1978 as below:

$$
\begin{aligned}
&Min_{\psi,\lambda} \ \psi_j \\
&\sum_{i=1}^{N} \lambda_i y_{ri} \geq y_j; \quad r = 1,...,R \\
&\sum_{i=1}^{N} \lambda_i x_{si} \leq \psi_j x_j; \quad s = 1,...,S \\
&\lambda_i \geq 0; \quad \forall i
\end{aligned}
\tag{3-0}
$$

Where $y_i = (y_{1i}, y_{2i},..., y_{Ri})$ is the output vector, $x_i = (x_{1i}, x_{2i},..., x_{si})$ is the input vector. Solving above equation for each one of the N container terminals of the sample, N weights and N optimum solution found. Each optimum solution ψ_j^* is the efficiency indicator of container terminal j and, by construction satisfies $\psi_j^* \leq 1$. Those container terminals with $\psi_j^* < 1$ are considered inefficient and $\psi_j^* = 1$ are efficient. Charnes et al. (1978) model constant returns to scale (CRS) was modified by Banker et al (1984) by adding the restriction $\sum_{i=1}^{N} \lambda_i = 1$, this has generalising model to variable returns to scale (VRS) as below;

$$
\begin{aligned}
&Min_{\vartheta,\lambda} \ \vartheta_j \\
&\sum_{i=1}^{N} \lambda_i y_{ri} \geq y_j; \quad r = 1,...,R \\
&\sum_{i=1}^{N} \lambda_i x_{si} \leq \vartheta_j x_j; \quad s = 1,...,S \\
&\sum_{i=1}^{N} \lambda_i = 1; \lambda_i \geq 0; \quad \forall i
\end{aligned}
\tag{4-0}
$$

Charnes et al. (1978) from DEA-CCR discover the objective evaluation of overall efficiency and identify the resources and estimates the amounts of the identified inefficiencies. Thus it is called constant return to scale (CRS). Albeit, Banker et al, (1984), DEA-BCC remove the constraint from the CCR model by adding $\sum_{i=1}^{N} \lambda_i = 1$ thus, BCC is

able to distinguish between technical and scale inefficiencies by (i) estimating pure technical efficiency at the given scale of operation and (ii) identifying whether increasing, decreasing or constant return to scale possibilities are present for further exploitation. It is called as variable return to scale. Therefore, for CCR efficient is required both scale and technical efficient, BCC efficient is only required technically efficient.

4. Container Terminal Efficiency Using Data Envelopment Analysis

A firm's productivity is usually measured by comparing its actual production volume with a production frontier. Wang et al. (2005), productivity measurement can be classified into using a parametric frontier approach or a non-parametric frontier approach. In the parametric frontier approach, the productivity frontier is estimated in a particular functional form with constant parameters. Liu (1995) uses a stochastic parametric frontier approach on 25 world ports, whereas Estache et al. (2001) studies 14 Mexican ports in order to investigate the efficiencies gained after port reform. Other studies on port performance with a stochastic parametric frontier approach are Tongzon and Heng (2005), Cullinane and Song (2003), Cullinane et al. (2002) and Notteboom et al. (2000). Besides this, Coto-Millan et al. (2000) uses a stochastic cost function approach on 27 Spanish ports. De and Ghosh (2002) examined 12 Indian ports using a time-varying production function approach. On the other hand, the non-parametric frontier approach assumes no particular functional form for the frontier. The most commonly used non-parametric frontier technique is DEA.

There are numerous studies on port performance with DEA approach, some of them are Wang et al (2002), Tongzon (2001), Valentine and Gray (2001), Martinez-Budria et al. (1999), Roll and Hayuth (1993), Barros and Athanassiou (2004), Turner et al. (2004) and Cullinane et al. (2004, 2005). Recently, Wang and Cullinane (2006) apply DEA on 104 European ports across 29 countries. Besides this, Park and De (2004) introduced a four-stage alternative DEA approach on Korean ports.

4.1 Discussion of Input and Output

The research is using 6 container terminals in Peninsular Malaysia as DMU. The data used in this research is from the year 2003 to 2010. The presentation of results are based on general output oriented DEA-CCR and DEA BCC in obtaining efficiency score. The research is used DEA-Solver Pro 7 version for analysis of data for the model. Golany and Roll (1989) highlight that the number of DMUs should be at least twice the number of inputs and outputs for the homogeneity reason. In container terminal industry, the handling equipments for operation are varied from each other. In this case, it is the index approach is used for certain inputs to avoid homogeneity i.e., for quay crane;

Quay Crane's index = Number of quay cranes × average lifting capacity

We use average lifting capacity to indicate average lifting of quay crane at wharf. By using this, we are able to average maximum lifting capacity of quay crane. The lifting capacity of quay cranes are different according to it series i.e., Westport Malaysia container terminal informs its quay crane specification Table 1 (Appendix). Table 2 represents input and output for the study.

The descriptive statistics for analysis which represent maximum, minimum, average and standard deviation of inputs and output. The maximum and minimum of TTA are 1800 and 27.28 m^2 respectively. The average and standard deviation for TTA are 723.876 and 535.758 m^2 respectively. Maximum and minimum quay crane index are 1980 and 120 respectively with the average and standard deviation at 724.73 and 508.79. as for output, the maximum and minimum T (million) Teus at 5988.066 and 108.108 respectively with the average and standard deviation at 2189.48 and 1776.94. The descriptive statistics shows the variant in result as the container terminals in Peninsular Malaysia are different in size, equipment and throughput. In addition, correlation between variables indicate no weak correlation, the lowest at medium correlate (0.607) yet significant. The highest correlations are 0.946 and 0.944 between BL and T, also YS and T. It means all variables are accepted as there are no strong correlations among variables with positive correlation.

6. Result and Discussion

The analysis of the research is using panel data from 2003 to 2010 of container terminals in Peninsular Malaysia. Table 3 represents example of raw data for inputs and output target for data analysis. Each DMU represent each year i.e., AW 2003- TTA (I) (410), T (O) 2300770 etc. The inputs target are TTA, MD, BL, QC, YS, V and GL and Output target is T.

Table 4 represents ranking score for efficient and inefficient DMUs. There are 19 DMU that represent efficient = 1, the other 29DMUs are inefficient. The most inefficient DMU is FK03, in which represent inefficient of 0.607. In general, the bottom 3 of inefficient DMUs are FK04 (0.689) and FK05 (0.668). Rank 20 (FK10) represents closely efficient for DMUs. The efficient DMUs are i.e., EPP10, AW03, CP10 etc. The inefficient DMUs means that between inputs and output, the utilisation of resources are not at maximum as possible, where there are improvement can be done by container terminal operators in achieving an efficient container terminal.

Table 5 and 6 represent efficiency and weight inputs and output for DEA-CCR and DEA-BCC. The analysis for DEA-CCR efficiency i.e., CP05 (efficient) in which utilisation of all inputs and output are = 1. It shows that utilisation between inputs and output significantly = 1. It means, all resources allocated for that time are at maximum with the output that produces by container terminal. It is also efficient for CP05 when tabulate by using DEA-BCC (Table 6). It means, between constant and variable returns to scale are nothing different for CP05. The inefficient DMU (FK03) by using DEA-CCR is the most inefficient at 0.607 Table 5. However, by using DEA-BCC the analysis is slightly higher at 0.880 (Table 6). The reason is DEA-BCC only requires technical efficient in determining the efficiency level rather than DEA-CCR in which, require both scale and technical efficiency to be efficient.

The efficiency returns to scale for DEA-BCC depicts 6 efficient DMUs are increase return to scale and projected are 14 DMUs. The constant return to scale efficient DMUs are 19 and projected is 9 DMUs. There are no decreasing in return to scale for all DMUs. The summary efficiency return to scale represent that there are 19 constant DMUs in compare with previous year i.e., CP03, CP04 and CP05 (efficient = 1) and there are 9 constant projected DMUs i.e., BN07 and BN08 (0.931 and 0.947) respectively. There are 6 DMUs increase return to scale i.e., FK03 (0.8807) and FK04 (1), FK05 (0.970) and FK06 (1). Furthermore, another 14 increase in projected return to scale DMUs i.e., EPP05 (0.894) and EPP06 (0.917), FK08 (0.894) and FK09 (0.930)

7. Conclusion

The analysis of technical efficiency for this research covers DEA-CCR and DEA-BCC. There are differences in analysis between DEA-CCR and DEA-BCC, where DEA-BCC is only focused on technical efficiency. However, DEA-CCR covers both scale and technical efficiency. The output-oriented ranking for DEA-CCR represents 19 efficient DMUs and the most inefficient DMU (FK03 -0.607). Alternatively, DEA-BCC represents 25 efficient DMUs, with the most inefficient is AW04 (0.725).The additive model without convexity constraints will characterise DMUs as efficient. Therefore, the characterise DEA-CCR for its characteristic, and then CCR's DMU is efficient. It is also similar to DEA-BCC, however because the constraint in DEA-CCR, CCR-efficiency does not exceed BCC-efficiency.

Therefore, inefficient result between DEA-CCR and DEA-BCC are different when the most inefficient DMU for DEA-BCC is AW04 (0.725) if compared with DEA-CCR is FK03 (0.607). It means, the size of container terminal does not reflect significant efficiency towards throughput obtained. The research reflects that container terminal operators must allocate efficiently between all the inputs to ensure utilisation of resources are obtained.

References

Ali, A.I., and Seiford, L.M., (1993) "the mathematical programming approach to efficiency analysis" in The Measurement of Productive Efficiency: Technique and Applications, Fried *et al*. Editors, Oxford University Press, NY Banker, R.D., Charnes, A. and Cooper, W.W.,(1984). Some models for estimating technical and scale inefficiencies in data envelopment analysis. *Mgmnt Sci.*, 30, 1078–1092.

Barros, C.P. and Athanassiou, M. (2004) Efficiency in European seaports with DEA: Evidence from Greece and Portugal, Maritime Economics and Logistics, Vol. 6, 122-140

Carrese, S. and Tatarelli, L., (2011).Optimising the Stacking of the Intermodal Transport Units in an Inland Terminal: An Heuristic Procedure. Procedia Social and Behavioral Science 20. Pp. 994-1003.

Charnes, A., W.W. Cooper and E. Rhodes, (1978). "Measuring the Efficiency of Decision Making Units" *European Journal of Operational Research* 2(6), pp. 429–444.

Charnes, A., W.W. Cooper, A.Y. Lewin and L.M. Seiford, 1994a. *Data Envelopment Analysis: Theory, Methodology and Application.* Norwell: Kluwer Academic Publishers.

Charnes, A., W.W. Cooper and L.M., (1994b). "Extension to DEA Models" In A. Charnes, W.W. Cooper, A. Y.

Coto-Millan, P., Banos-Pino, J. and Rodriguez-Alvarez, A. (2000) Economic efficiency in Spanish ports: Some empirical evidence, Maritime Policy and Management, Vol. 27, 169-174.

Cullinane, K. and Song, D.W. (2003) A stochastic frontier model of the productive efficiency of Korean container terminals, Applied Economics, Vol. 35, 251-267.

Cullinane, K., Ji, P. and Wang, T.F. (2005) The relationship between privatization and DEA   estimates of efficiency in the container port industry, Journal of Economics and Business,Vol. 57, 433-462.

Cullinane, K., Song, D.W. and Gray, R. (2002) A stochastic frontier model of the efficiency of major container terminals in Asia: Assessing the influence of administrative and ownership structures, Transportation Research Part A: Policy and Practice, Vol. 36, 743-762.

Cullinane, K., Song, D.W., Ji, P. and Wang, T.F. (2004) An application of DEA Windows analysis to container port production efficiency, Review of Network Economics, Vol. 3, 186-208.

De, P. and Ghosh, B. (2002) Productivity, efficiency and technological change in Indian ports, International Journal of Maritime Economics, Vol. 4, 348-368.

Estache, A., Gonzalez, M. and Trujillo, L. (2001) Technical efficiency gains from port reform: The potential for yardstick competition in Mexico. Policy Research Working Paper 2637, The World Bank, Washington, D.C.

Farrell, M. J., 1957, The Measurement of productive efficiency, Journal of Royal Statistical Society A, 120, 253-281.

Golany, B and Roll, Y. (1989) An Application Procedure for DEA. International Journal of Management Science. Vol.17, No.3, pp 237-250.

Hariharan, K.V. (2002). *Container and Multimodal Transport Management*. Mumbai: SPD Pvt.Ltd.

Hayuth, Y.   (1987).   *Intermodality: Concept and Practice*.   London: Lloyd's of London Press Ltd.

Hayuth, Y. (1994). The Overweight Container Problem and International Intermodal Transportation. *Transportation Journal*. 34 (2): 1-9.

Kasypi, M and Shah, MZ (2012) Agile Supply Chain for Container Terminal. *International Journal of Sustainable Development*. 04: 05: 69-82.

Levinson, M. (2006). *How Shipping Container Made the World Smaller and the World Economy Bigger*. New Jersey. Princeton University Press

Levinson, M and Zhu, S. (2011) The Hierarchy of Roads, the Localityof Traffic and Governance. Transport Policy, 19, pp. 147-154.

Liu, Z. (1995) The comparative performance of public and private enterprises, Journal of Transport Economics and Policy, Vol. 29, 263-274.

Lovell, C.A.K (1993) "Production Frontier and Production Efficiency in The Measurement of Production Efficency": Technique and Appllications Fried at al. Editors, Oxford Univeristy press, NY.

Mali, P. (1978) Improving Total Productivity: MBO Strategies for Business, Government, and Not-for-Profit Organisation. John Wiley& Son Inc.

Martinez-Budria, E., Diaz-Armas, R., Navarro-Ibanez, M. and Ravelo-Mesa, T. (1999) A study of the efficiency of Spanish port authorities using data envelopment analysis, International Journal of Transport Economics, Vol. 26, 237-253.

Notteboom, T., Coeck, C. and van den Broeck, J. (2000) Measuring and explaining the relative efficiency of container terminals by means of Bayesian Stochastic Frontier models, International Journal of Maritime Economics, Vol. 2, 83-106.

Park, R.K. and De, P. (2004) An alternative approach to efficiency measurement of seaports, Maritime Economics and Logistics, Vol. 6, 53-69.

PWD (2009) http://www.jkr.gov.my/ accessed July, 2009

Roll, Y. and Hayuth Y. (1993) Port performance comparison applying data envelopment analysis (DEA), Maritime Policy and Management, Vol. 20, 153-161.

Ramanathan, R (2003) An Introduction to Data Envelopment Analysis: A Tool for Performance Measurement. New Delhi, Sage Publications

Sumanth, D. J.(1984). *Productivity Engineering and Management*. New York: McGraw-Hill

Talley, W. K. (2000). Ocean Container Shipping: Impact of a Technological Improvement. *Journal of Economics Issues*. 34 (4): 933-948

Tongzon, J. (2001) Efficiency measurement of selected Australian and other international ports using data envelopment analysis, Transportation Research Part A: Policy and Practice, Vol. 35, 113-128.

Tongzon, J. and Heng, W. (2005) Port privatization, efficiency and competitiveness: Some empirical evidence from container ports (terminals), Transportation Research Part A: Policy and Practice, Vol. 39, 405-424.

Turner, H., Windle, R. and Dresner, M. (2004) North American container port productivity: 1984-1997, Transportation Research Part E: Logistics and Transportation Review,Vol. 40, 339-356.

UNCTAD (1993). United Nations Publlication. http://www.unctad.org/en/docs/1993en.pdf. Accessed 8 January 2007

UNCTAD (2001). Implementation Multimodal Transport Rules (Advance Copy). http://unctad.org/en/Docs/posdtetlbd2.en.pdf Accessed, June 2012.

Valentine, V.F. and Gray, R. (2001) The measurement of port efficiency using data envelopment analysis. Proceedings of the 9th World Conference on Transport Research, Seoul, South Korea, 22-27 July 2001.

Wang, T.F. and Cullinane, K. (2006) The efficiency of European container terminals and implications for supply chain management, Maritime Economics and Logistics, Vol. 8,82-99.

Wang, T.F., Cullinane, K. and Song, D.W. (2005) Container Port Production and Economic Efficiency. Palgrave Macmillan, Basingstoke.

Wang, T.F., Song, D.W. and Cullinane, K. (2002) The applicability of data envelopment analysis to efficiency measurement of container ports. Conference Proceedings of the IAME   2002, Panama.

World Bank. (2005) Road Transport Service Efficiency Study: India. Energy&Infrastructure Operations Division South Asia Regional Office.

Notes

Appendix A- Example for data: Table(s)

Table 1. Capacity of Quay Crane

Type	Capacity (Tones)	LASR (Above Deck)	Out Reach (Rows on Vessel)
1-Mitsubishi	35	27M(3)	36M(11-12)
1-Hitachi	30	33M(5)	42M(14-15)
9-Impsa	40	34M(6)	48M(16-17)
2-Noel	41	32M(5)	45M(15-16)
3-Mitsui	41	38M(7)	52M(18-19)
4-Mitsui	41	38M(7)	59M(21-22)
14-Mitsui Twin-lift	50 Single 2x30 Twin	40M(8)	62M(22-23)

(source: Westport Malaysia Container Terminal, 2011)

Table 2. Input and Output

Input(s)	Output(s)
X1: Total Termianl Area in M^2 (TTA)	Y1: Throughput (TEU: '000) (T)
X2: Maximum draft in meter (MD)	
X3: Berth length in meter (BL)	
X4: Quay crane index (QC)	
X5: Yard stacking index (YS)	
X6: Vehicles (V)	
X7: Number of gate lanes (GL)	

www.iiste.org

Table 3. Inputs and Output Target for Data Analysis

DMU	(I)TTA	(I)MD	(I)BL	(I)QC	(I)YS	(I)V	(I)GL	(O)T
AW	410	15	2000	360	28551.3	140	8	2300770
BN	846	14	2379	916.8	33135	307	10	2540465
CP	1200	15	2160	1375.2	23405.76	414	3	3168702
DJ	144.56	14	760	200	1437.216	92	3	750466
EPP	578	12	931	308.8	1547.75	225	3	688171
FK	50	14	400	120	300	26	2	108108

Table 4. DEA-CCR Ranking Score (Output-oriented)

Rank	DMU	Score
1	EPP10	1
20	FK10	0.995605
46	FK04	0.689216
47	FK05	0.668564
48	FK03	0.607029

Table 5. Efficiency and Weight of inputs and output of each DMU

(Output-oriented DEA, CRS)

No.	DMU	Score	X(1) TTA	X(2)MD	X(3) BL	X(4) QC	X(5) YS	X(6) V	X(7) GL	Y(1) T
1	AW03	1	7.16E-04	0	2.40E-04	3.80E-04	3.18E-06	0	0	4.35E-04
6	FK03	0.607029	1.87E-03	0	0	0	5.18E-03	0	0	9.25E-03
15	CP05	1	8.27E-05	1.93E-02	0	0	3.99E-06	1.03E-03	2.65E-03	2.51E-04

Table 6. Efficiency and Weight of inputs and output of each DMU

(Output-oriented DEA, VRS)

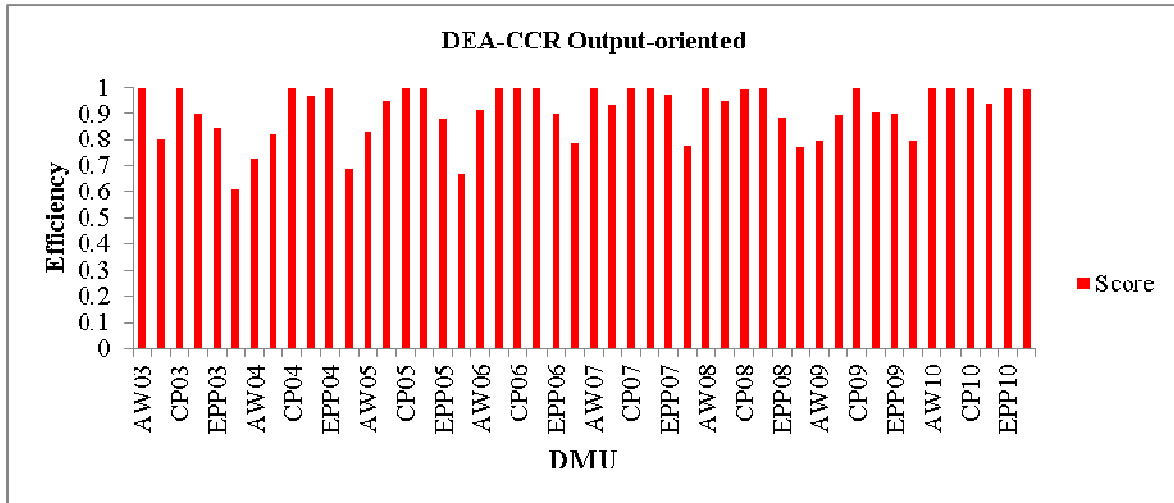| No.	DMU	Score	X(0)	X(1) TTA	X(2) MD	X(3) BL	X(4) QC	X(5) YS	X(6) V	X(7) GL	Y(1) T
1	AW03	1	0	7.16E-04	0	2.40E-04	3.80E-04	3.18E-06	0	0	4.35E-04
6	FK03	0.880743	-1.32467	0	0	1.68E-03	1.96E-03	5.00E-03	1.95E-03	0	9.25E-03
15	CP05	1	0	8.27E-05	1.93E-02	0	0	3.99E-06	1.03E-03	2.65E-03	2.51E-04

Appendix-B

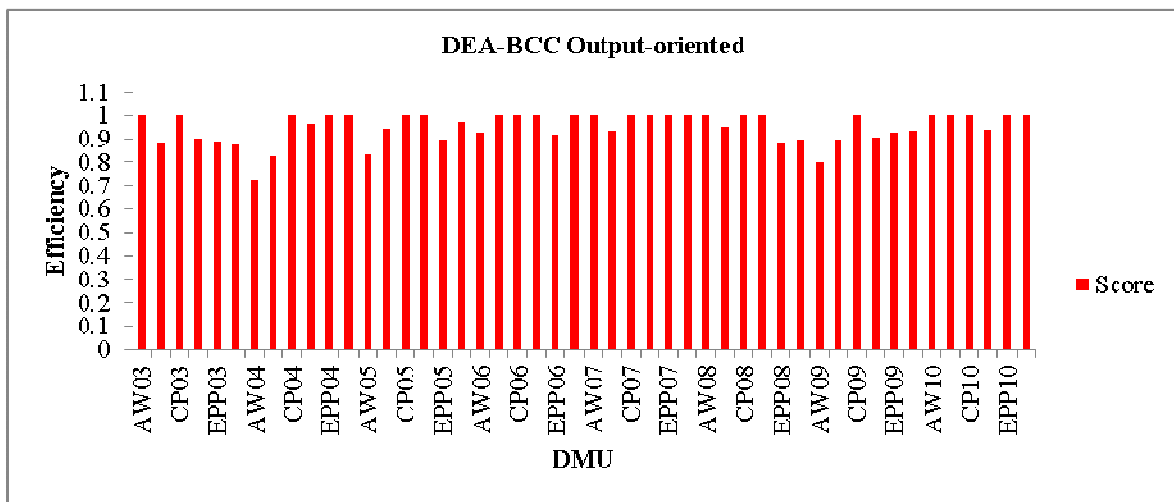Figure 1-0: Container Terminal Yearly Efficiency(Output-oriented Efficiency Rating)

Figure 2-0: Container Terminal Yearly Efficiency(Output-oriented Efficiency Rating)

This academic article was published by The International Institute for Science, Technology and Education (IISTE). The IISTE is a pioneer in the Open Access Publishing service based in the U.S. and Europe. The aim of the institute is Accelerating Global Knowledge Sharing.

More information about the publisher can be found in the IISTE's homepage:
http://www.iiste.org

CALL FOR PAPERS

The IISTE is currently hosting more than 30 peer-reviewed academic journals and collaborating with academic institutions around the world. There's no deadline for submission. **Prospective authors of IISTE journals can find the submission instruction on the following page:** http://www.iiste.org/Journals/

The IISTE editorial team promises to the review and publish all the qualified submissions in a **fast** manner. All the journals articles are available online to the readers all over the world without financial, legal, or technical barriers other than those inseparable from gaining access to the internet itself. Printed version of the journals is also available upon request of readers and authors.

IISTE Knowledge Sharing Partners

EBSCO, Index Copernicus, Ulrich's Periodicals Directory, JournalTOCS, PKP Open Archives Harvester, Bielefeld Academic Search Engine, Elektronische Zeitschriftenbibliothek EZB, Open J-Gate, OCLC WorldCat, Universe Digtial Library , NewJour, Google Scholar