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The Efficiency Measurement of Container Ports in Thailand by Using DEA Windows Analysis Approach

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Abstract:
In the past two decades, Thailand had development in container port's infrastructure where was near all coastal provinces. Currently, recent trend of using container for commerce has demand increase every year. The aim of this paper is to measure and analyse the efficiency of Thai container port by using Data Envelopment Analysis (DEA) Windows Analysis Approach. This paper examined many literatures on efficiency of container port together with feasible input and output variable. The cross-section data has been used for analyzing the result by considering its multiple time periods. The DEA Windows analysis based on variable return to scale (VRS) is used to measure the feasible input oriented by using BCC model. The findings exhibit that Bangkok port has efficiency more than other ports. Phuket and Laemchabang port have efficiency approach 100 percent and Songkla port has efficiency is least. Therefore, as the empirical results of this paper can help Thai government examines the efficiency of infrastructure investment and operation of container port in Thailand for leading to improve plan and creating competitive advantage. Moreover, this paper also helps private sector knows about the trend and direction of operation's improving.

Keywords: *Efficiency, container port, DEA Windows Analysis, Thailand*

1. Introduction

After Thailand has been changed regime of country from absolute monarchy to be democracy in year 1932.There was anidea beganto build about the government's port. Dredging project of Phraya River had been nominated for creating new channel. The objective of this project was focused on maritime affairs by allowing large ships through the new channel where was created by humans. Thus, Thai government sent the letter asked for help to Office of League of Nations at Geneva, Switzerland. After two years, Office of League of Nations had sent three container port' export came to survey about commerce, economic and construction site of government's port. Those experts had proposed two areas for construction government's port where located in SamutPrakan province and Khlong Toei district. Then, Thai government had decided to choose Khlong Toei district was a construction area. In year 1935, Thai government had established board of government's port for complement about this project. Until year 1947, government's port had been named was Bangkok port and opened service in that year. Since then, the Bangkok port had started the undertaking of sea transport in Thailand (Port Authority of Thailand, 2016). In the past three decades, the sea transport in Thailand had been developed and added more container ports where were near coastal areas. The objective of the container port's expansion was to reduces congestion, distant and time from Bangkok port and also added some convenient to industrial area.

Until year 2012, the economic crisis had effected to demand and supply of global shipping market. This crisis had effect short time to the sea transport in Thailand. Moreover, as the statistics of containerisation during 2004-2012, Singapore, Malaysia and Thailand had the numbers of TEU more than other countries in South East Asian, respectively (United Nations Conference on Trade and Development, 2016). Before consolidation of ASEAN, there is some trouble that has effected to sea transport in Thailand because of container port in Thailand could not increase efficiency equivalent container ports in Malaysia and Singapore. Therefore, the objective of this paper is to measure the efficiency of container port in Thailand and also identify the direction of container port's policy in the feature. This paper employsDEA windows analysis approach to analyse the efficiency of four container ports. The dataset of four container ports has been designed to compare their operational efficiency by using three periods of the time. Young et al. (2012) improved the overall maritime transport in ASEAN. This study had evaluated the efficiency in port operations of 32 container ports in

ASEAN nations by applying the Data Envelopment Analysis approach (DEA). This study concluded that there were2 out of 32 ports in 2010 had been calculated as efficient ports. Moreover, the results show that there are two major findings are identified. Firstly, some port has operational inefficient need to improve size and structure by following the port where has operational efficient. Secondly, as the results of this study, they could be used to guide international port candidates and country in term of the development of co-operation programme with Korea by improving the performance and developing the infrastructures of ill-equipped ports. Zghidi (2014) assessed the Tunisian ports both of efficiency and inefficiency by using the DEA Window approach. This approach can help to measure the rank of operational efficiency of ports and evaluates how they develop during six-year period from 2005 to 2010. After measuring of ports, the results have confirmation that country's infrastructure are filled-land scarcity and low platforms in those ports.
According to the research problem, this paper has been explained the important context as follow. Section 2 overviews previous literatureas concern in this filed. Section 3 presents related methodology and examine the correlation coefficients of input and output variables. Section 4 exhibits the data and reports empirical results. Finally, section 5 will have summary and conclusions about all important contexts.

2. Literature Review

2.1. DEA Windows Analysis

Last 3 decades ago, DEA were widely used to evaluate and solve overcoming the problem of firm's operation. Farrell (1957) proposed a new idea for helping firms regarding efficiency measurement. In 1978, Charnes, Cooper and Rhodes developed the idea of Farrell and also applied linear programming to evaluate the frontier of production technology. This idea had been designed to apply the linear programming into production technology frontier region under condition of constant returns to scale (CRS). Then, this idea had been named was CCR model. The Model of DEA had been improved and formalized by Banker, Charnes and Cooper (BCC), (1984), and became BBC model. This model had element of technical and scale efficiency which was used in the economist field.
In year 1985, DEA windows analysis was first introduced for measuring the efficiency in cross-sectional. It was used to evaluate efficiency both in the CCR and BCC models by considering the efficiency trends of operation unit under period of time. As many previous literatures of DEA windows analysis have been applied to many fields which were exhibited as follow; Chung et al. (2008) considered the selection of product family mix within semiconductor fabricator by applying DEA window analysis approach. This study had examined the long-term effectiveness in term of productivity and profit within manufacturing by evaluating the change of operational efficiency during period of time. The result can provide direction to the fabricator strategies that aggregate operational planning to adjust efficiency of manufacturing area. Yang and Chang. (2009) studied the efficiency measurement of Taiwan's integrated telecommunication firms by leading DEA window analysis approach to measured firm's efficiencies. The first finding of this research can show that the acquisitions are obtained from higher scale efficiency of short run. The second finding can conclude that the improving of firm's strategies such as enlarging market share affectto improving financial portfolios which it can help firm reach the better scale size. Moreover, last finding can state that government can drive enterprises become privatize state-owned and liberalize in market by focusing on strengthen competitiveness. Weng et al. (2008) interested an extended DEA model in area of hospital performance evaluation. This study aimed to use window analysis approach for measuring the performance within multiple time periods. According to hospital data, the finding in empirical results of this study can state that the proposed model can launch benchmarks for hospital over multiple time periods. Pulina et al. (2010) investigated the relationship between scale size and operational efficiency of the Italian hospitality sector by using window DEA approach. This paper had analysis about the efficiency of hotels cover all 20 regions in Italy, its results summarized that both of technical and scale efficiencies had been calculated by considering an efficiency comparison amongst hotel industry. Thus, the policy of Italian hospitality sector is identified from the concept of high efficiency scores by observing from low efficiency scores. Salem et al (2010) extended DEA windows analysis in the case study of Middle East and East African seaports. This paper had focused for measuring the operational efficiency of 22 cargo seaports. The findings within the results can show that the efficiency DMUs under super-efficiency DEA have efficiency score more than normal efficiency DEA. Cullinane et al. (2010) analysed the efficiency and production of container port by applying DEA approaches. In this paper, a panel data of 25 container ports was evaluated for observing their efficiency. As the results, this paper provides a basis for considering competitiveness advantage in container ports and can obtain the benchmark for reference in term of best practice. Moreover, the obtaining of benchmark can lead to identify the specific sources of inefficiency. Danijela et al. (2012) interested the efficiencies measurement in Serbia port. This study used DEA window analysis approach for measuring the efficiency of ports and also observed about the possibility of changes in period of time. According to evaluation of port efficiency in Serbia, the inefficiency sources and formulate proposals for adjusting were investigated. As the findings can mention that the progresses in evaluation of port efficiency have relation with port productive activities. Moreover, VanDyck (2015) assessed efficiency in West Africa ports by using DEA windows Analysis. There were six port had been collected the panel data for analysis and DEA window analysis was used to consider inefficiency DMUs over time.

2.2. Input and Output Variables

Kevinet al.(2004) studied container port in term of production and efficiency by applying DEA windows analysis for measuring the efficiency trends. This study has considered quay length, terminal area, quayside gantry, yard gantry and straddle carrier are input variables. Moreover, this study also considers throughput (TEU) is output variable. Ada and Chee, (2007) has analysed productivity of container ports in Malaysia by applying DEA model. They identify total yard area, number of yard cranes, total berth length and

number of quay Cranes are input variables. They also identify container throughput (TEUs), number of ship calls are output variables. In the same year, SoonHoo et al. (2007) analysed efficiency and calculate ranking of major Container Ports in Northeast Asia. This study uses DEA approach to measure efficiency operation of Container Ports. There are four input variables consist of berth length, terminal area, number of quay cranes and number of yard equipment. Moreover, they identify container throughput is output variable. Salem et al. (2008) analysed the efficiency of Middle Eastern and east African seaports. This study is designed to use DEA window analysis for analysis the efficiency trend. In this research, they provide berth length, storage area and handling equipment are input variables and also provide ship Calls and Throughput are output variables. Cullinane and Wang, (2010) measured the efficiency and production of container port. This study applies DEA approaches to analyse the panel data of input and output variables. This study uses quayside gantry, yard gantry, straddle carrier is input and also uses container throughput, terminal length and terminal area are output. In additional, Van Dyck(2015) assessed operational efficiency in West Africa port by applying DEA approach to analyse the data. This study identifies input variable which consist of total quay length, terminal area, number of quayside cranes, number of yard gantry cranes, number of reach stackers and also identified container throughput to be output variable. According to previous literature reviews, the conclusion of variables is showed in Table 1.

The 1 Theconclusion of input and output variables from literature reviews

Author/year	Topic	Input	Output
Kevin et al (2004)	An Application of DEA Windows Analysis to Container Port Production Efficiency	Quay length (m), Terminal Area (ha), Quayside Gantry (number), Yard Gantry (number), Straddle Carrier (number)	Throughput (TEU)
Ada and Lee, (2007)	Productivity Analysis of Container Ports in Malaysia: A DEA Approach	Total Yard Area (Sqm), Number of Yard Cranes, Total Berth Length (m), Number of Quay Cranes	Container Throughput (TEUs), Number of Ship calls
So et al (2007)	Efficiency Analysis and Ranking of Major Container Ports in Northeast Asia: An Application of Data Envelopment Analysis	Berth Length (m), Terminal Area (m2), Number of Quay Cranes, Number of Yard Equipments	Container Throughput (TEU)
Salem et al, (2008)	Efficiency of Middle Eastern and East African Seaports: Application of DEA Using Window Analysis	Berth Length(m), Storage Area(m2), Handling Equipment	Ship Calls (Units), Throughput (Tons)
Cullinane and Wang, (2010)	The efficiency analysis of container port production using DEA panel data approaches	Quayside gantry (number), Yard gantry (number), Straddle carrier (number)	Container throughput (TEU), Terminal length (m), Terminal area (ha)
Van Dyck, G. K. (2015)	Assessment of Port Efficiency in West Africa Using Data Envelopment Analysis	Total quay length (m), Terminal area (ha), Number of quayside cranes, Number of yard gantry cranes, Number of reach stackers	Container throughput (TEUs)

Table 1

3. Methodology

3.1. DEA Windows Analysis Approach

According to the previous using of DEA windows analysis approach, they adopted this approach to analysed the panel data by considering the number of N DMU's (n=1, N) base on T periods (t=1, N) where had identifying r inputs and s outputs. Hence, as the observation of DEA windows analysis, it can exhibit a sample of N x T where n is in period t, (DMU_t^n) which has r dimensional input vector $x_t^n = (x_{1t}^n, x_{2t}^n, \dots, x_{rt}^n)$ and s dimensional output vector $y_t^n = (y_{1t}^n, y_{2t}^n, \dots, , y_{st}^n)$. After that the observations of window k_w with k×w will be started in period of k, 1≤ k ≤ T with width w, 1≤ w ≤T − k. Thus, matrix of inputs can be presented as follow:

$$x_{kw} = (x_k^1, x_k^2, \dots, x_k^N, x_{k+1}^1, x_{k+1}^2, \dots, x_{k+1}^N, x_{k+w}^1, x_{k+w}^2, \dots, x_{k+w}^N)(1)$$

Meanwhile, matrix of outputs can be presented as:

$$y_{kw} = (y_k^1, y_k^2, \dots, y_k^N, y_{k+1}^1, y_{k+1}^2, \dots, y_{k+1}^N, y_{k+w}^1, y_{k+w}^2, \dots, y_{k+w}^N)(2)$$

According to DEA window problem under condition of constant returns to scales (CRS), DMUt has been generated by using the linear programing model as follow:

$$\theta'_{k_w t} = \min_{\theta,\lambda} \theta$$

s.t.

$$-x_{k_w}\lambda + \theta x'_t \geq 0$$
$$Y_{k_w}\lambda - y_t \geq 0$$
$$\lambda_n \geq 0 (n = 1, \dots N\ x\ w)(3)$$

Moreover, The VRS model has been considered in this paper which has been explained by $\sum_1^N \lambda_n = 1$ (Banker et al., 1984). This study aims to use the condition of variable returns to scales (VRS) for accordance with the real case that the container ports have different

sizes. The size has influence to the ability of output's efficiency which make hypothesis of CRSmodel is irrational. Hence, the condition of VRS frontier can make best practice level of output from input. As solving linear programing model, VRS model can be exhibited as follow:

$$\theta'_{k_w t} = \min_{\theta,\lambda} \theta$$

s.t.

$$-x_{k_w}\lambda + \theta x'_t \geq 0$$
$$Y_{k_w}\lambda - y_t \geq 0$$
$$\sum_1^N \lambda_n = 1$$
$$\lambda_n \geq 0 (n = 1, \dots N \; x \; w) (4)$$

3.2. Data Selection

In this paper, the data selection has been considered from the panel data in annual reports of four container ports in Thailand which was collected during 2006-2013. All data relate with operation, service and infrastructure of ports such as number of port, length of port, number of crane, warehouse area and quantity of product. Thus, the general statistics of container ports in Thailand can be exhibited in Table 2 and 3.

List name of container port	Number of port (Port)	Length of port (Meter)	Number of crane(Crane)	Warehouse area (Square meter)	Quantity of product (Million tons)
1. Bangkok	56	10,000	112	133,408	136.24
2. Laemchabang	144	55,528	336	657,856	418.25
3. Songkhla	24	4080	20	53,760	11.86
4. Phuket	16	2272	12	12,000	2.21

Table 2: General statistics of four container ports for year 2006-2013.
Source: Port Authority of Thailand (2014)

	Number of port (Port)	Length of port (Meter)	Number of crane (Crane)	Warehouse area (Square meter)	Quantity of product (Million tons)
Max	18	6941	46	82232	66.03
Min	2	284	1	1500	0.1
Average	7.5	2246.25	15	26782	17.7675
SD	6.3443	2733.9614	16.4088	32474.9790	21.5479

Table 3: Summary of statistics on input and output data
Source: Author's calculation

As the correlation coefficients of inputs and outputs of four container ports, variable selections are necessary to control the validity of all results of this paper. Correlated factors have been used to check accuracy of data set and also used to drop the number of inputs and outputs under condition of DEA model. With measuring the efficiency in four container ports of Thailand, is tonicity is used to explain the correlation of inputs and outputs. For instant when there is input or output has very weak correlation with other inputs or outputs, this input or output should be eliminated from dataset. In contrast, when input or output has strong correlation with other inputs or outputs, it means that input or output has same change or concord with other inputs or outputs. According to the results in Table 4, the findings can explant that there is strong correlation between variables because the score of correlation in overall variables have more than 0.80. Moreover, these variables have positive correlation with other inputs or outputs. Thus, this paper can summarize that if input variable has some change, it will reflect some change to output variable.

Input and output variables	Number of port (Meter)	Length of port (Meter)	Number of crane (Crane)	Warehouse area (Square meter)	Quantity of product (Million tons)
Number of port	1	0.9859	0.9954	0.9909	0.9733
Length of port	0.9859	1	0.9805	0.9991	0.9564
Number of crane	0.9954	0.9805	1	0.9849	0.9855
Warehouse area	0.9909	0.9991	0.9849	1	0.9610
Quantity of product	0.9733	0.9564	0.9855	0.9610	1

Table 4: Correlation coefficients of input and output variables
Source: Author's calculation

3.3. Determination of Input and Output Variables

According to previous literature reviews of container ports, input and output variables were used in efficiency measurement of ports operation in an interval. The selection of input and output variables have important in term of corrected measuring. The technic of selection in this paper has considered from the quantity of using in previous studies. Thus, the determination of input variables can be generated such as number of port, length of port, number of crane and warehouse area. Moreover, output variable consist of quantity of product within container port. Therefore, overall variables in this study are concluded in Table 5.

Input and Output Variables		References
Inputs	Number of port	Kevin et al (2004), Ada and Lee, (2007), So et al (2007), Salem et al, (2008), Cullinane and Wang, (2010) and Van Dyck, G. K. (2015)
	Length of port	
	Number of crane	
	Warehouse area	
Outputs	Quantity of product	

Table 5: Determination of input and output variables

4. Empirical Results and Analyses

According to adopting of DEA window analysis, it can measure all of efficiency decision-making units (DMUs) within container ports of Thailand over time for the period 2006-2013. The DEA window analysis has been decided to use input oriented model under variable returns to scale (VRS) for evaluating input and output variables. This approach has been observed by considering 32 observations from (8 years x 4 ports) Moreover, Cooper et al. (2007) have determined the number of windows and the number of ‘‘different’’ units from the formula: Where w = k – p + 1 and where d = n x p x w, respectively (where n = number of firms, p= length of window, w = number of windows, k = number of periods and d = number of ‘‘different’’ units). Thus, as the formulas above can be obtained the number of windows as follow:

Number of windows = 8 – 4 + 1 =3,

Number of ‘‘different’’ units = n x p x w = 4 x 4 x 3 = 48

After calculation, there are 48 different units have been used to consider the port’s operational efficiency. According to DEA window analysis, rows and columns have been used to examine the trends and stability properties (Cooper et al., 2007). Moreover, the length of window has been defined by selecting from three, four or five-year window. Thus, the length of window can be explained as follow: the first set of data in window is port efficiency which has the length from the first four years. At the same time, the second set in window will consist of the data from the second, third, fourth and fifth year, all of data in each window is made different which leads to differences in port efficiency. Therefore, the results of DMUs in window have been evaluated from the comparison of port efficiency over the eight years.

According to model 4 of window analysis approach, input oriented model under variable returns to scale (VRS) is used to measure ports efficiency. This paper is defined the length of window by considering three durations. Six rows of window have explained the results of one port. Moreover, each port in this paper is put into a different DMU under three-year windows as showing in Table 6. As the results as appear in Table 6 and Figure 1, when consider at the comparison score of efficiency between four ports, Bangkok port is clear that this port has stable operational efficiency during 2006-2013.Phuket port has operational efficiency is subordinate. During 2006-2013, there are operational efficiencies are equal to 0.9999 except year 2012 which has operational efficiency is equal to 1. Moreover, Songkhla port has significant decrease in efficiency since 2009. There are score of operational inefficiencies when consider the end of the period in all windows. The number of port, length of port, number of crane and warehouse area are considered be poorly utilized. Overall input variables can increase their utilized over the current. In contrast, Laemchabang port has significant increase in efficiency when look particular point at the end of the period in all windows. Most of all input variables have been used to support the increasing of used in this port. Laemchabang port is going to develop and improve efficiency in its port.

As the average of port efficiency in Table 6, first rank of port efficiency average is Bangkok port where has high efficiency equal to 1. This port can be mentioned that a port has the highest efficiency and it hasn’t any weakness point in its operation. Second rank of the port efficiency average is Phuket port where has score of average efficiency less than Bangkok port. This port has operational inefficiency where should be improved. Third rank of the port efficiency average is Laemchabang port where has development of port operation. This port has continually increased its operation from port inefficiency become port efficiency. Fourth rank of port efficiency average is Songkhlaport, this port has port inefficiency more than other ports. The operational efficiency should be improved in variables by increasing input and output. Most of decreasing could be achieved by buying or renting the port equipment from outside.

Container port	2006	2007	2008	2009	2010	2011	2012	2013	Average
Bangkok	1.0000	1.0000	1.0000						
		1.0000	1.0000	1.0000					
			1.0000	1.0000	1.0000				
				1.0000	1.0000	1.0000			
					1.0000	1.0000	1.000		
						1.0000	1.0000	1.0000	1.0000
Laemchabang	0.8609	1.0000	0.9946						
		0.9516	0.9467	1.0000					
			0.8769	0.9292	1.0000				
				0.8149	0.8905	1.0000			
					0.8840	1.0000	1.0000		
						1.0000	0.9807	1.0000	0.9517
Songkhla	0.9999	1.0000	0.9999						
		1.0000	0.9999	0.9999					
			0.9999	1.0000	0.7845				
				1.0000	0.7662	0.7703			
					0.7118	0.7151	0.6666		
						0.7141	0.6666	0.7439	0.8633
Phuket	0.9999	0.9999	0.9999						
		0.9999	0.9999	0.9999					
			0.9999	0.9999	0.9999				
				0.9999	0.9999	0.9999			
					0.9999	0.9999	1.0000		
						0.9999	1.0000	0.999	0.9999

Table 6: The average efficiency of container ports for years 2006-2013
Source: Author's calculation

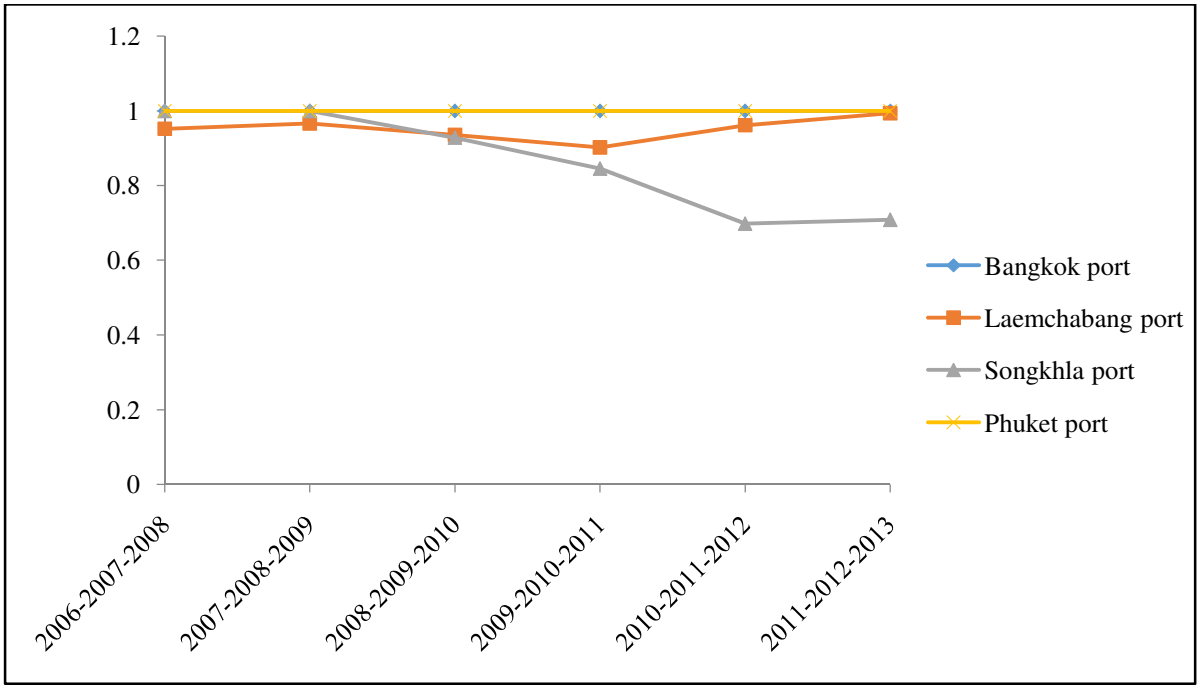

Figure 1: The efficiency trend analysis of container port.
Source: Author's calculation

5. Summary and Conclusions

This paper has been designed to measure the efficiency of four container port in Thailand during 2006-2013 by using DEA windows analysis approach. This approach has been used to evaluate the panel data base on time series. The data set has been collected from the panel data of four container ports. The input variables are composed of number of port, length of port, number of crane and warehouse

area. The output variable is the quantity of product. Meanwhile, the selections of input and output variables are determined by following the number of popularity used in previous study. Moreover, this paper has used correlation coefficients for checking relation between overall variables. As the results can show the correlations core of variables that they have more than 0.80 and have positive correlation with other inputs or outputs. Thus, these findings can explant that there are strong correlation and have significant relationship between variables. According to the analysis of this paper, the results can overview that the port efficiency of Bangkok port was 1 or 100% during 2006-2013, while Phuket port has efficiency was 0.9999 or 99% which is close 1 and other two ports have efficiency do not reach 1 or 100%. Thus, this paper can summarize two main reasons of data analysis as follow. First, when the port has efficiencies is suggested to keep the port operation or increase the size of port. Second, when the port has low efficiencies is suggested to find more new customers and increase the renting of port equipment from outside.

According to the results of four container ports, the comparisons of port operation have been used to examine effectiveness and ineffectiveness of ports. The examination is important to identify the strategy and improve operation, capacity and service within ports. Moreover, port where has operational efficiency will be used to identify the benchmark to port where has inefficiency. Therefore, this paper can help government identify the direction of policy in the further and also helps private sector knows about the trend and direction of operation's improving.

6. References

i. Ada S.F.NG.,& Chee X.L. (2007). Productivity analysis of container ports in Malaysia: a DEA approach. Journal of the Eastern Asia Society for Transportation Studies, 7.

ii. Banker, R.D., Charnes, A. & Cooper, W.W. (1984). Some Models for Estimating Technical and Scale Inefficiencies in Data Envelopment Analysis. Management Science,30(9), 1078–92.

iii. Charnes, A., Clark, C.T., Cooper, W.W. &Golany, B. (1985). A Developmental Study of Data Envelopment Analysis in Measuring the Efficiency of Maintenance Units in the U.S. Air Forces in R.G. Thompson and R, N, Thrall, eds. Annals of Operations Research, 2, 95–112.

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

v. Chung, S., Lee, A., Kang, H., & Lai, C. (2008). A DEA window analysis on the product family mix selection for a semiconductor fabricator. Expert Systems with Applications, 35(1-2), 379-388.

vi. Cooper, W.W., Seiford, L.M.,&Tone,K.(2007). A comprehensive text with models, applications, references and DEA-Solver software.NewYork: Springer, 327.

vii. Cullinane, K., &Wang, T. (2010). The efficiency analysis of container port production using DEA panel data approaches. OR Spectrum, 32(3), 717-738.

viii. Danijela P., Aleksandar R., Zlatko H., &Vladeta C. (2012). DEA window analysis for measuring port efficiencies in Serbia. PROMET Traffic and Transportation, 24(1), 63-72.

ix. Farrell,M. J. (1957). The Measurement of Productive Efficiency. Journal of the Royal Statistical Society. SeriesA (General), 120(3), 253-290.

x. Kevin C., Dong-Wook S., Ping J., &Teng-Fei W. (2004). An application of DEA windows analysis to container port production efficiency. Review of Network Economics,3(2).

xi. Port Authority of Thailand. (2016). The history of Port Authority of Thailand. Available at: http://www.port.co.th/sitenew/index.php

xii. Pulina, M., Detotto, C., &Paba, A. (2010). An investigation into the relationship between size and efficiency of the Italian hospitality sector: A window DEA approach. European Journal of Operational Research,204(3), 613-620.

xiii. Salem Al-Eraqi, A., Mustafa, A., & Tajudin Khader, A. (2010). An extended DEA windows analysis: Middle East and East African seaports. Journal of Economic Studies, 37(2), 208-218.

xiv. SoonHoo S., JaeJon and K., Geon C., & Do-Kwan K. (2007). Efficiency Analysis and Ranking of Major Container Ports in Northeast Asia: An Application of Data Envelopment Analysis. International Review of Business Research Paper, 3(2), 486 - 503

xv. Yang, H.-H., & Chang, C.-Y. (2009). Using DEA window analysis to measure efficiencies of Taiwan's integrated telecommunication firms. Telecommunications Policy, 33(1-2), 98-108.

xvi. Young J. S., Dong K. R., & Myo N. A. (2012). An analysis of container port efficiency in ASEAN. Journal of Navigation and Port Research International Edition,36(7), 535-544.

xvii. United Nations Conference on Trade and Development. (2016).Containerisation international yearbook 2012. Available at: http://unctad.org/en/Pages/Home.aspx.

xviii. Van Dyck, G. K. (2015). Assessment of Port Efficiency in West Africa Using Data Envelopment Analysis. American Journal of Industrial and Business Management, 05(04), 208-218.

xix. Weng, S.-J., Wu, T., Blackhurst, J., & Mackulak, G. (2008). An extended DEA model for hospital performance evaluation and improvement. Health Services and Outcomes Research Methodology, 9(1), 39-53.

xx. Zghidi, N. (2014). Sea port efficiency: the case of Tunisian maritime ports. International Journal of Advanced Information Science and Technology, 23.