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An Analysis of Container Port Efficiency in ASEAN

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Abstract : *In order to improve the overall ASEAN maritime transport network, each port's efficiency is regarded as a crucial factor that should be calculated periodically. This study evaluated the relative efficiency of container port operations of 32 ports belonging to 9 ASEAN nations using Data Envelopment Analysis (DEA). It found that 2 out of 32 ports in 2010 were measured as efficient ports. This study yielded two major findings. Firstly, the ports assessed as inefficient need to benchmark similar ports in size and structure from the ports that are assessed as efficient to improve their efficiency. Secondly, these results could be used to determine potential candidates and country for an international port development co-operation programme with Korea to improve the performance of the entire ASEAN port network by developing the infrastructures of ill-equipped ports.*

Key words : *ASEAN Port, Port Operation, Port Management, Port Efficiency, DEA*

1. Introduction

In ASEAN regions, as a massive consumption market with more than 600 million population in accordance with an increasing economic development, consumption for premium commodities is increasingly ongoing. As a result, a maritime logistics market such as a transportation for trade and cargo handling has been enlarged. By strengthening co-operation between Korea and ASEAN in maritime logistics, co-operation strategies are being sought for mutual benefits. Recently, the trade between Korea and ASEAN is significantly increased by boosting economic co-operation that leads them to discuss over creating Korea-ASEAN Free Trade Zone. The proliferation of economic co-operation between Korea and ASEAN has a positive influence on the maritime sector.

In addition, Korea government has implemented national strategies, which can combine two aspects: co-operation for developing maritime logistics, policy for supporting firm investments in emerging markets. By doing so, it contributes to developing influence on emerging markets, supporting oversea investments for related private firms. Most ports in ASEAN suffer lack of facilities to handle increasing container throughput with low efficiency due to a deterioration. A port can not only create the employment and income in the port industry as well as relevant industries, but also affect to induce direct investments on the regions.

Therefore, ASEAN, combinations of almost developing countries, needs to promote a development by improving port efficiency in order to have both direct and indirect positive impacts on the economy.

Nonetheless, the literature on container port efficiency has mainly focused on ports in advanced markets or compared them in terms of regions (Wu and Goh, 2010). Notwithstanding a strategic importance of an emerging market such as ASEAN there has few research on identifying container port efficiency in ASEAN owing to a lack of data and interest. Therefore, this current study may firstly explore the efficiency of ports in ASEAN in an effort to both suggest a blueprint for each port manager in ASEAN and disclose objective data in assisting ASEAN port networks, i.e. an international port development co-operation programme such as ODA with Korea by developing ill-equipped ports that may enhance an overall ASEAN maritime transport networks.

In particular, this research aims at analysing port efficiency of 32 ports in 9 countries in ASEAN using DEA. The Decision Making Units (hereafter DMUs) are divided into efficient ports and inefficient ports. Thus, this study seeks specific information concerning how a particular port is relatively inefficient compared to other ports, and

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suggests how to become an efficient port.

Based on measured efficiency according to DEA-CCR, this research puts forward how a particular port increase efficiency with dedicated solutions. Hence, it contributed to a decision making when government attempts to carry out international co-operation for port development or private firms carry out strategies in an effort to penetrate into oversea port sectors in ASEAN.

2. The Changing Environment of the Shipping and Port Industry in ASEAN

2.1 Upward Growth of Maritime Trade in ASEAN

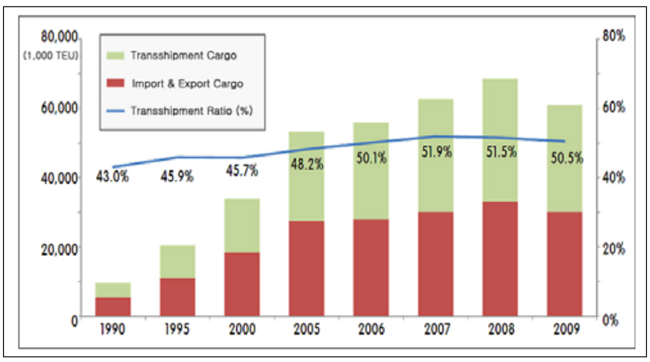
ASEAN countries have recently expanded port facilities and developed new ports so as to deal with increasing both import and export cargoes, which are dramatically derived from an economic development. In particular, some nations such as Singapore and Malaysia possess developed feeder routes to connect between them and adjacent countries due to increased trade volumes. So there is rising competition between them to preoccupy the strategic positioning since these routes are regarded as an important gateway connecting between North America and Europe. Furthermore, it is expected that global shipping lines attempt to start penetrating their business into the ASEAN market owing to a new demand for maritime transportation. Competition among them is getting fierce in case of over-capacity of vessels.

In terms of cargo throughput, ASEAN showed the lowest levels except for South Asia and Africa in 1980s. In 2011 it has the 3rd largest cargo throughputs followed by Far-East Asia and Western Europe because of a constant increase for the last three decades. The container throughputs in ASEAN accounted for 5% in 1980 and 15% in 2011 respectively with a sudden increase. Particularly, the rate of transshipment cargo seems to be relatively higher than other regions. The drastic increase of cargo volume is shown in the following Fig. 1.

2.2 Changing Environment of Ports in ASEAN

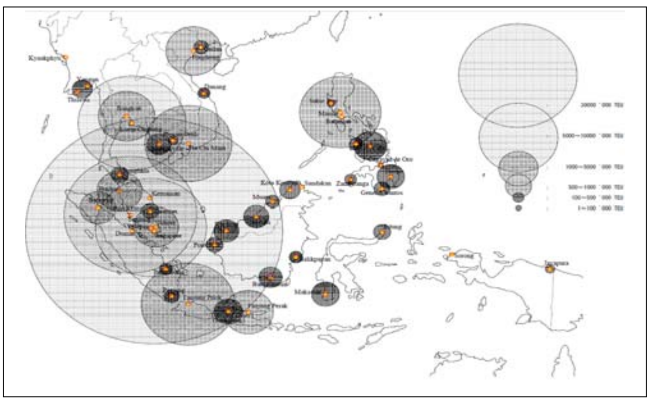
International maritime routes in ASEAN, which are centred on Port of Singapore, Port of Tanjung Pelepas in Malaysia, Port of Laem Chabang in Thailand and Port of Tanjung Priok in Indonesia are currently interconnected with the all over the world. The Port of Singapore, which is geographically located in a central route connecting between Asia and Europe, and Asia and America as a role of transshipment, is ranked 2nd in the world in terms of container throughput. Port Klang in Malaysia and Port of Laem Chabang in Thailand are rapidly developing in an effort to compete with the Port of Singapore. The Port Klang tries to make sure that more than 6,000 TEU container ships can come alongside the berth by constructing new berths for Post-Panamax container ships with 15 metre depth, connecting more than 300 ports in the world. Moreover, Vietnam has participated in competition of new port developments through attracting foreign capital. Container facilities of Port of Ho Chi Mihn is planned to be relocated in Vung Tao and Banpong because of its deeper water depth.

Meanwhile, Indonesia has intensively fostered Port of Tanjung Priok, which ranks 20th in terms of container throughput, whilst Philippine also prepares developing Port of Manila in accordance with an increase of container cargo in the near future. However, except for aforementioned ports, port infrastructure and facilities in most ports in



Note : The figure in 2009 was forecasted
Source : Drewry Shipping Consultants, 2008

Fig. 1 Container Throughputs in ASEAN



Source : Japan OCDI (2010)

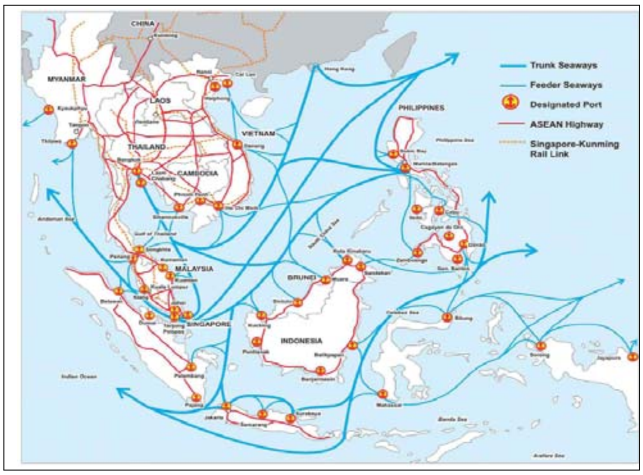
Fig. 2 Container Volumes in ASEAN Ports

ASEAN have lagged far behind due to the lack of terminals, cranes and cargo handling space such as container yards, causing low productivity. On top of these, a number of ports are located in inland areas, so it is difficult for ships to go through on account of depth limit. Also, the productivity in ports is extremely low because container cargoes are often handled in multi-purpose terminals. The lack of port IT system should be solved as well. It is urgently necessary to improve the low logistics infrastructure in order to build efficient maritime transport networks in ASEAN.

Fig. 2 shows annual total cargo volumes including bulk cargoes and container throughput in ASEAN network ports. With Port of Singapore as a centre of hub port, there are hub, transshipment and feeder ports in ASEAN, showing the huge difference on cargo throughputs between them.

In order to deal with significantly increasing maritime cargoes, ASEAN focuses on building port networks to connect between trunk and feeder seaways. ASEAN port associations designated 47 ports in ASEAN as important regional ports for research on examining a list of network ports, and organised network of trunk and feeder seaways as shown in Fig. 3. The cargo volumes in those port account for 95% in ASEAN. Ministry of Land, Transport and Maritime Affairs in Korea has planned to support above ports development since 2010, and more co-operation projects will be carried out in near future.

The current research evaluated 32 ports based on data availability of DEA method among aforementioned 47 ports in ASEAN.



Source : ASEAN Maritime Transport Development Study, ALMEC Corp. 2002.

Fig. 3 Port Networks in ASEAN

3. Literature Review on Port Efficiency Evaluation

3.1 Previous Research

The followings indicate literature on port efficiency using DEA. Ha (2009) investigated an efficiency of 35 ports in USA and North-East Asia from 2005 to 2007 through CCR and BCC analysis.

Park (2010a) examined the efficiency of 45 ports in East Asia, Europe and North America. Input elements includes the number of berth, total berth length, CY size, the number of cranes and depth. Output factor involves TEU and the number of shipping liners for ship calls.

In addition, Park (2010b) suggested the efficiency of 11 container terminals for transshipment including Busan and Kwangwang port. Input factors such as CY size, the number of container crane, the number of yard crane and the number of yard tractor were employed. It appointed the number of transshipment TEU as a output factor to explore the efficiency.

Roll and Hayuth (1993) evaluated ports in developed countries using CCR model in DEA mainly focusing on a theoretical exploration rather than actual application since no data were analysed. They contributed to firstly employing CCR model, based on constant returns to scale, in the maritime and port sector.

Notteboom, Coeck and Van den Broeck (2000) verified the efficiency of 36 terminals in Europen ports through Bayesian Stochastic Frontier Model and also analysed 4 terminals in Asia for a benchmark. They employed berth length, terminal size and the number of cranes as input variables and TEU as a output variable, and contended that each container terminal's maximum efficiency cannot exceed 0.85. In addition, they asserted the followings. First, container terminals in Northern Europe generally shows a slightly higher degree of efficiency than those in Southern Europe. Second, large size terminals represent higher levels of efficiency than small size terminals, but small size terminals in mega ports can attain a high degree of efficiency by learning effect. Third, terminals in a hub port have a higher level of those in a feeder port. Fourth, there is no correlation between ownership forms in terminals and an efficiency.

Barros (2003) revealed incentive regulation and efficiency in five Portugues Port Authority. Input measures employed are the number of employees and value of listed asset. Output measures embraces a number of factors such as the number of ship, cargo throughput, gross tonnage of ships, market share rate, bulk cargo handling, TEU, break bulk volume, liquid cargo volume and net income.

Cullinane et al. (2004) explored a level of efficiency of 25 container ports in the world by using DEA Windows analysis. Input variables adopt berth length, terminal size, the number of cranes in berth, the number of yard cranes. TEU was used as an output variable.

Al-Eraqi et al. (2008) studied 22 cargo ports in Middle East and East Africa employing cross-sectional data and Window Model. The advantage of this model is to boost the discriminatory power by dynamically increasing the total number of DMUs so that it is easier to track port performance and stability over time.

Chudasama and Pandya (2008) investigated sources of inefficiency of port autorities of 12 ports in India, which is an emerging market, adopting both DEA-CCR and DEA-BCC.

Cheon et al. (2009) found that global port improvements and R&D would have an impact on degrees of container ports from 1991 to 2004. They identified both efficiency changes and the reason of efficiency fluctuation by interpreting Malmquist productivity index, and argued followings. First, they viewed economies of scale as an important element without unconditional leverage. Second, due to global competition, it is possible for ports to overcome external weakness by changing governance and increasing capital. Third, aggressive investment on R&D barely play a crucial role in port competition due to easy imitability.

Table 1 Literature Review

Author	Variables: Inputs	Variables: Outputs	DMUs
Tongzon (2001)	· Number of cranes · Number of container berths · Number of tugs · Terminal area · Delay time · labor	· TEU · Ship working rate	· 4 Australian & other 12 international port
Park (2010a)	· Number of berth · Total berth length · CY size · Number of cranes · Depth	· TEU · Ship calls	· 45 ports in East Asia, Europe and North America
Wu & Goh (2010)	· Terminal area · Total quay length · pieces of equipment	· TEU	· 22 ports in BRIC, the Next-11 and G7
Rios & Maçada (2006)	· The number of cranes · Berth length · The number of employees · The number of yard equipment · CY size	· TEU · Average umber of containers per hour per ship	· 23 MERCOSUR ports
Al-Eraqi et al(2007)	· Berth length · Storage area · Handling equipment	· TEU · Ship calls	· 22 ports in Middle East and East Africa
Park (2010b)	· CY size · Number of container crane · Number of yard crane · Number of yard tractor	· Number of transshipment TEU	· 11 terminals in Busan & Kwangwang port

3.2 Implications of Previous Studies

Although a number of scholars investigate port performance and port efficiency using DEA model both in Korea and abroad, there are several limitations on facts that it is difficult to explore reciprocal correlations of factors, which influence on general port performance and port efficiency, and quantitatively examine relative importance. The ultimate aims for evaluating efficiency and quantification are to improve port efficiency, so it is generally recognised that results of the study can be applied in a practical way to improve the efficiency of container terminals.

There are several limitations on previous literature. First, they are solely concerned with a few terminals or ports, which have a large number of TEU handled or ranked high in terms of TEU handling so they tend to ignore ports in emerging markets, having great potential for new value-added creation. Second, although some studies use cross-sectional analysis, it hardly contributed to comprehensive results in regards to efficiencies by simply calculating variation compared to previous year. Third, previous research only focused on specific regions, resulting in a fact that they hardly suggested difference in efficiencies according to port characteristics such as an economic size or country size.

4. DEA Methodology

4.1 DMU Selection

This research chooses 32 ports as DMUs in nine countries in ASEAN except for ports which we can not acquire an appropriate data. Secondary data were collected through Containerisation International Yearbook, brochures, the Internet websites and finally the study on "Identifying required improvement areas in ASEAN network port performance and capacity", based among others, on regular forecasts of maritime trade and requirements by Ministry of Land, Transport and Maritime affairs in Korea in 2011. Thus, among a variety of techniques such as SFA, FDH and DEA, this study adopts DEA approach since this method is not only non-parametric but also no need to have an explicit priori determination of relationships between input and output variables.

Table 2 DMUs according to Countries

Country	DMUs (Name of Container ports)
Brunei (1)	Muara
Cambodia (1)	Sihanoukville
Indonesia (4)	Belawan, Makassar, Tanjung Perak, Tanjung Priok
Malaysia (9)	Bintulu, Johor, Klang, Kota Kinabalu, Kuantan, Kuching, Penang, Sandakan, Tanjung Pelepas
Myanmar (2)	Yangon, Thilawa
Philippine (9)	Batangas, Cagayan De Oro, Cebu, Davao, General Santos, Iloilo, Manila, Subic Bay, Zamboanga
Singapore (1)	Singapore
Thailand (2)	Bangkok, Laem Chabang
Vietnam (3)	Da Nang, Hai Phong, Ho Chi Minh City
Sum	32

4.2 Input and Output Variables

In general, production systems create outputs by combining inputs and technology after qualitative transforming process. If such systems attempt to apply to particular firms or public business, the selection of inputs and outputs is essential in terms of productivity and efficiencies. When it comes to general firms, both inputs such as labor, capital and land and outputs such as goods and services are used to analyse.

On the other hand, large public business such as a port, which is regarded as social overhead capital facilities, is likely to has vague forms of inputs and outputs. Therefore, it is noted that choosing input and output variables is demanding when measuring port efficiency. Dowd and Leschine (1990) asserts that the productivity for input variables depend on labor, capital and land, so they can measure the efficiency of a container terminal that depends on the efficient use of these variables by quantifying the efficient use of those. Generally, researchers have suggested that the determinants for container terminal efficiency are port facilities, equipment, productivity of port, price competitiveness and services and so forth.

Therefore, a number of researchers have chosen various and different inputs and outputs variables due to ambiguity in regards with deciding such variables. Moreover, there is constraint on data, which is common to gain and applicable to DEA. Another important aspect of DEA is that it does not measure absolute efficiency, but relative or comparative efficiency.

Consequently, after through interviews with practitioners and researchers in the port industry in ASEAN, the current study decides to use input variables such as the number of berth, berth length, CY size, the number of cranes, which may be not only considered as compulsory elements in ports, but also almost employed in previous research, while cargo throughput in TEU is selected as an output variable according to the same criterion above.

Table 3 Selection of Input and Output Variables

Input and Output		References
Inputs	Number of berth (ea)	Tongzon(2001), Itoh(2002), Park(2010a), Rios & Macada(2006), Ryoo et al.(2006),
	Berth lengh (m)	Park(2010a), Wu & Goh(2010), Notteboom et al.(2000), Rios & Macada(2006), Al-Eraqi et al.(2007), Cullinane et al.(2004), Ryoo et al.(2006), Park et al.(2007), Lu & Park(2010)
	CY size (m^2)	Tongzon(2001), Itoh(2002), Cullinane et al.(2004), Park(2010a), Wu & Goh(2010), Rios & Macada(2006), Al-Eraqi et al.(2007), Park(2010b), Ryoo et al.(2006), Park et al.(2007)
	Number of cranes (ea)	Tongzon(2001), Itoh(2002), Cullinane et al.(2004), Park(2010a), Rios & Macada(2006), Al-Eraqi et al.(2007), Ryoo et al.(2006), Park et al.(2007)
Outputs	TEU	Tongzon(2001), Itoh(2002), Cullinane et al.(2004), Park (2010a), Al-Eraqi et al.(2007), Rios & Macada(2006), Ryoo et al.(2006), Park et al.(2007), Lu & Park(2010)

5. DEA Results

5.1 DEA-CCR Output-Oriented Model Results

The current study obtained results using DEA-SOLVER and EMS, both of which are non-commercial softwares. DEA evaluation features two forms: Input oriented and Output oriented. The former focuses on minimising the input so that a desired degree of output can be gained. On the other hand, the latter aims at maximising the output while maintaining inputs at a constant level (Rio & Macada, 2006). Output oriented model is often applied to port, steel and automotive industry since a large amount of money is invested at once and inputs are normally capital goods.

The CCR model supposes constant returns to scale, whilst BCC model presumes variable returns to scale. Both Input and Output oriented models persue maximum efficiency while minimising intputs and maximising outputs.

This study aims at employing Output oriented CCR

Model to evaluate efficiency. The choice of CCR is justified by the fact that container terminals operate under constant returns to scale.

1) DEA-CCR Model Results

Fig. 4 shows port efficiency in ASEAN. The port of Tanjung Pelepas and port of Kota Kinabalu have higher levels of efficiency. With using EMS, super efficiency is found in these ports, meaning that efficiency value is 1 (perfect) in case of SOLVER programme.

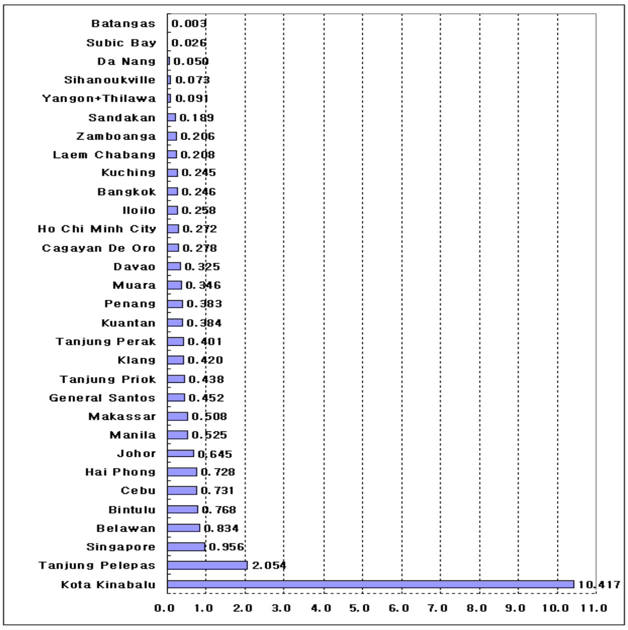


Fig. 4 CCR Model Results

2) CCR Model Efficiency Ranking and Benchmarking

Table 4 demonstrates efficiency ranking, benchmarking and lambda (λ). After checking efficiency ranking, inefficient ports that require improvement can benchmark an efficient port by either decreasing inputs or increasing outputs in the future. If certain ports' efficiency value is 1, it can be interpreted as efficient, and it serve as benchmarks for the sector. In contrast, it can be viewed as inefficient if efficiency value is less than 1. As a result, there are two ports that are efficient. The DMU, which is under 1, has benchmarking ports. For example, Bangkok port, which has 0.246 efficiency value, should benchmark Kota Kinabalu or Tanjung Pelepas port by estimating linear production function per parts with lambda(λ) of inputs and outputs of them, so the efficiency value of Bangkok port is 0.246 compared to hypothetical DMUs.

Table 4 Efficiency Ranking and Benchmark (CCR)

Ranking	DMU	efficiency value	Benchmark (Lambda)
1	Kota Kinabalu	1	Kota Kinabalu - 1
1	Tanjung Pelepas	1	Tanjung Pelepas - 1
3	Singapore	0.956	Kota Kinabalu-6.222, Tanjung Pelepas-4.981
4	Belawan	0.834	Kota Kinabalu-0.264, Tanjung Pelepas-0.113
5	Bintulu	0.768	Kota Kinabalu-0.335, Tanjung Pelepas-054
6	Cebu	0.731	Kota Kinabalu-1.104, Tanjung Pelepas-0.080
7	Hai Phong	0.728	Kota Kinabalu-3.067, Tanjung Pelepas-0.277
8	Johor	0.645	Kota Kinabalu-0.351, Tanjung Pelepas-0.207
9	Manila	0.525	Kota Kinabalu-5.247, Tanjung Pelepas-0.729
10	Makassar	0.508	Kota Kinabalu-0.929, Tanjung Pelepas-0.097
11	General Santos	0.452	Tanjung Pelepas-0.043
12	Tanjung Priok	0.438	Kota Kinabalu-0.529, Tanjung Pelepas-1.428
13	Klang	0.420	Tanjung Pelepas-2.903
14	Tanjung Perak	0.401	Kota Kinabalu-0.571, Tanjung Pelepas-0.915
15	Kuantan	0.384	Kota Kinabalu-0.552, Tanjung Pelepas-0.040
16	Penang	0.383	Tanjung Pelepas-0.417
17	Muara	0.346	Kota Kinabalu-0.390, Tanjung Pelepas-0.046
18	Davao	0.325	Kota Kinabalu-1.160, Tanjung Pelepas-0.136
19	Cagayan De Oro	0.278	Kota Kinabalu-0.192, Tanjung Pelepas-0.078
20	Ho Chi Minh City	0.272	Kota Kinabalu-1.005, Tanjung Pelepas-2.154
21	Iloilo	0.258	Kota Kinabalu-0.349, Tanjung Pelepas-0.042
22	Bangkok	0.246	Kota Kinabalu-1.920, Tanjung Pelepas-0.767
23	Kuching	0.245	Tanjung Pelepas-0.217
24	Laem Chabang	0.208	Kota Kinabalu-1.692, Tanjung Pelepas-3.590
25	Zamboanga	0.206	Tanjung Pelepas-0.051
26	Sandakan	0.189	Kota Kinabalu-0.488, Tanjung Pelepas-0.024
27	Yangon+Thilawa	0.091	Kota Kinabalu-1.457, Tanjung Pelepas-0.553
28	Sihanoukville	0.073	Tanjung Pelepas-0.481
29	Da Nang	0.050	Kota Kinabalu-1.368, Tanjung Pelepas-0.255
30	Subic Bay	0.026	Tanjung Pelepas-0.167
31	Batangas	0.003	Tanjung Pelepas-0.043

3) Efficiency Improvement Ways for Inefficient Ports

There is the efficiency value to be improved if a port is considered as inefficient. It is fairly certain that when each port is projected to efficient frontier DEA allows inefficient ports to know how to improve them. Since efficient DMUs do not have any slack, this helps inefficient DMUs to benchmark. In general, DEA tends to improve efficiency by decreasing inputs or increasing outputs.

Table 5 illustrates projection values for improving efficiency of DMUs. There is no change of inputs and outputs if score data is over 1. For instance, followings demonstrate how Muara (0.346) improves its efficiency respectively.

It is recommended that Muara port should not only reduce the number of berths by 25.81% and berth length by 51.97% due to an enormous slack, but also improve TEU by 189.15% in order to reach efficient frontier. The large slack in these facilities needs to consider reforming their role for improving port efficiency.

Table 5 CCR Model Results of Projection

(Unit : ea, m, ㎡, ea, TEU)

Input/Output	Score Data	Projection	Difference	%
Muara	0.346			
Number of Berths	3	2.226	-0.774	-25.810%
Berth Length	765	367.418	-397.582	-51.970%
Total Area	56,070	56,070	0	0%
C/C	3	3	0	0%
TEU	120,000	346,977.724	226,977.724	189.150%
Sihanoukville	0.073			
Number of Berths	8	2.889	-5.111	-63.890%
Berth Length	1,040	1,040	0	0%
Total Area	1,408,600	577,777.778	-830,822.222	-58.980%
C/C	12	11.074	-0.926	-7.720%
TEU	210,200	2,888,888.889	2,678,688.889	999.900%
Belawan	0.834			
Number of Berths	2	2	0	0%
Berth Length	850	426.829	-423.171	-49.780%
Total Area	137,070	137,070	0	0%
C/C	4	3.928	-0.072	-1.790%
TEU	609,000	730,379.005	121,379.005	19.930%
Makassar	0.508			
Number of Berths	6	5.228	-0.772	-12.870%
Berth Length	850	850	0	0%
Total Area	120,000	120,000	0	0%
C/C	13	6.880	-6.120	-47.070%
TEU	385,000	758,511.147	373,511.147	97.020%
Tanjung Perak	0.401			
Number of Berths	11	8.347	-2.653	-24.120%
Berth Length	2,370	2,370	0	0%
Total Area	1,100,000	1,100,000	0	0%
C/C	40	23.901	-16.099	-40.250%
TEU	2,242,000	5,597,506.857	3,355,506.857	149.670%
Tanjung Priok	0.438			
Number of Berths	14	11.217	-2.783	-19.880%
Berth Length	3,450	3,450	0	0%
Total Area	1,716,000	1,716,000	0	0%
C/C	110	35.500	-74.500	-67.730%
TEU	3,800,000	8,670,306.351	4,870,306.351	128.170%
Bintulu	0.768			
Number of Berths	2	2	0	0%
Berth Length	480	348.087	-131.913	-27.480%
Total Area	66,450	66,450	0	0%
C/C	6	2.924	-3.076	-51.260%
TEU	299,000	389,373.283	90,373.283	30.230%
Johor	0.645			
Number of Berths	3	3	0	0%
Berth Length	760	689.745	-70.255	-9.240%
Total Area	250,000	250,000	0	0%
C/C	23	6.524	-16.476	-71.640%
TEU	844,856	1,309,940.486	465,084.486	55.050%
Yangon+Thilawa	0.091			
Number of Berths	11	10.602	-0.398	-3.620%
Berth Length	2,198	2,198	0	0%
Total Area	668,701	668,701	0	0%
C/C	21	20.001	-0.999	-4.760%
TEU	325,270	3,592,107.032	3,266,837.032	999.900%

※ Rounded off to four decimal places

(Unit : ea, m, ㎡, ea, TEU)

Input/Output	Score Data	Projection	Difference	%
Batangas	0.003			
Number of Berths	2	0.261	-1.739	-86.960%
Berth Length	240	93.913	-146.087	-60.870%
Total Area	200,000	52,173.913	-147,826.087	-73.910%
C/C	1	1	0	0%
TEU	897	260,869.565	259,972.565	999.900%
Cagayan De Oro	0.278			
Number of Berths	2	1.425	-0.575	-28.760%
Berth Length	300	300	0	0%
Total Area	94,000	94,000	0	0%
C/C	6	2.747	-3.253	-54.220%
TEU	139,978	502,702.300	362,724.300	259.130%
Cebu	0.731			
Number of Berths	6	6	0	0%
Berth Length	1,141	933.485	-207.515	-18.190%
Total Area	100,000	100,000	0	0%
C/C	13	7.360	-5.640	-43.380%
TEU	503,000	688,384.384	185,384.384	36.860%
Kuantan	0.384			
Number of Berths	3	3	0	0%
Berth Length	600	466.742	-133.258	-22.210%
Total Area	50,000	50,000	0	0%
C/C	4	3.680	-0.320	-8%
TEU	132,252	344,192.192	211,940.192	160.250%
Kuching	0.245			
Number of Berths	11	1.304	-9.696	-88.140%
Berth Length	1,248	469.565	-778.435	-62.370%
Total Area	933,000	260,869.565	-672,130.435	-72.040%
C/C	5	5	0	0%
TEU	320,000	1,304,347.826	984,347.826	307.610%
Penang	0.383			
Number of Berths	4	2.500	-1.500	-37.500%
Berth Length	900	900	0	0%
Total Area	670,000	500,000	-170,000	-25.370%
C/C	20	9.583	-10.417	-52.080%
TEU	958,476	2,500,000	1,541,524	160.830%
Sandakan	0.189			
Number of Berths	3	2.586	-0.414	-13.810%
Berth Length	500	388.801	-111.199	-22.240%
Total Area	31,000	31,000	0	0%
C/C	3	3	0	0%
TEU	45,000	238,256.178	193,256.178	429.460%
Manila	0.525			
Number of Berths	69	30.607	-38.393	-55.640%
Berth Length	7,252	5,189.556	-2,062.444	-28.440%
Total Area	893,678	893,678	0	0%
C/C	43	43	0	0%
TEU	2,815,004	5,363,686.791	2,548,682.791	90.540%
Kota Kinabalu	1			
Number of Berths	5	5	0	0%
Berth Length	689	689	0	0%
Total Area	3,600	3,600	0	0%
C/C	5	5	0	0%
TEU	188,642	188,642	0	0%
Iloilo	0.258			
Number of Berths	2	2	0	0%
Berth Length	2,100	331.975	-1,768.025	-84.190%
Total Area	52,000	52,000	0	0%
C/C	3	2.719	-0.281	-9.370%
TEU	82,558	319,597.969	237,039.969	287.120%

※ Rounded off to four decimal places

(Unit : ea, m, ㎡, ea, TEU)

Input/Output	Score Data	Projection	Difference	%
Laem Chabang	0.208			
Number of Berths	30	30	0	0%
Berth Length	10,300	8,919.863	-1,380.137	-13.400%
Total Area	4,313,800	4,313,800	0	0%
C/C	96	91.026	-4.974	-5.180%
TEU	4,537,833	21,857,776.134	17,319,943.134	381.680%
Da Nang	0.050			
Number of Berths	9	8.368	-0.632	-7.020%
Berth Length	1,493	1,493	0	0%
Total Area	310,805	310,805	0	0%
C/C	27	12.702	-14.298	-52.960%
TEU	89,000	1,787,429.164	1,698,429.164	999.900%
Hai Phong	0.728			
Number of Berths	17	17	0	0%
Berth Length	2,713	2,712.032	-0.968	-0.040%
Total Area	343,565	343,565	0	0%
C/C	49	21.711	-27.289	-55.690%
TEU	1,631,662	2,241,265.567	609,603.567	37.360%
Ho Chi Minh	0.272			
Number of Berths	32	17.951	-14.049	-43.900%
Berth Length	5,346	5,346	0	0%
Total Area	2,589,000	2,589,000	0	0%
C/C	114	54.577	-59.423	-52.130%
TEU	3,563,246	13,116,462.058	9,553,216.058	268.100%
Subic Bay	0.026			
Number of Berths	1	1	0	0%
Berth Length	560	360	-200	-35.710%
Total Area	263,200	200,000	-63,200	-24.010%
C/C	4	3.833	-0.167	-4.170%
TEU	26,026	1,000,000	973,974	999.900%
Zamboanga	0.206			
Number of Berths	2	0.306	-1.694	-84.720%
Berth Length	110	110	0	0%
Total Area	157,000	61,111.111	-95,888.889	-61.080%
C/C	2	1.171	-0.829	-41.440%
TEU	63,079	305,555.556	242,476.556	384.400%
Singapore	0.956			
Number of Berths	61	61	0	0%
Berth Length	17,300	15,046.913	-2,253.087	-13.020%
Total Area	6,000,000	6,000,000	0	0%
C/C	232	145.683	-86.317	-37.210%
TEU	29,697,000	31,061,802.890	1,364,802.890	4.600%
Bangkok	0.246			
Number of Berths	18	14.205	-3.795	-21.090%
Berth Length	2,980.500	2,980.500	0	0%
Total Area	927,810	927,810	0	0%
C/C	50	27.251	-22.749	-45.500%
TEU	1,222,048	4,966,683.540	3,744,635.540	306.420%
Davao	0.325			
Number of Berths	10	6.615	-3.385	-33.850%
Berth Length	1,093	1,093	0	0%
Total Area	167,500	167,500	0	0%
C/C	9	8.929	-0.071	-0.790%
TEU	336,647	1,035,388.916	698,741.916	207.560%
General Santos	0.452			
Number of Berths	9	0.261	-8.739	-97.100%
Berth Length	740	93.913	-646.087	-87.310%
Total Area	140,000	52,173.913	-87,826.087	-62.730%
C/C	1	1	0	0%
TEU	117,817	260,869.565	143,052.565	121.420%
Tanjung Pelepas	1			
Number of Berths	6	6	0	0%
Berth Length	2,160	2,160	0	0%
Total Area	1,200,000	1,200,000	0	0%
C/C	23	23	0	0%
TEU	6,000,000	6,000,000	0	0%

※ Rounded off to four decimal places

(Unit : ea, m, ㎡, ea, TEU)

Input/Output	Score Data	Projection	Difference	%
Klang	0.420			
Number of Berths	23	17.417	-5.583	-24.280%
Berth Length	6,270	6,270	0	0%
Total Area	10,050,300	3,483,333.333	-6,566,966.667	-65.340%
C/C	153	66.764	-86.236	-56.360%
TEU	7,309,779	17,416,666.667	10,106,887.667	138.270%

※ Rounded off to four decimal places

6. Conclusion

This study developed a model to measure efficiency among 32 ports in ASEAN, using Output-Oriented DEA-CCR technique, and shed a light on gaining insights into port efficiency in emerging markets. Since DEA permits port managers to identify the efficiency of their port, it can be used by them as a objective reference when they decide to develop their port facilities and improve performance.

It is noted in this empirical study that there was no correlation between port size and port efficiency since this research reports that the port of Tanjung Pelepas and port of Kota Kinabalu had the highest efficiency degrees that surpasses those in ASEAN in 2010. These ports serve as benchmarks for the sector. This demonstrates a fact that regardless of the huge difference in inputs and outputs between them any ports that plan their facilities based on the actual container throughput are capable of operating efficiently. In other words, Port of Kota Kinabalu deals with maximum container throughput in despite of small size facilities. This implication exactly lies in the same vein with Tongzon (2001).

Contrary to general expectations, Singapore port, which owns higher levels of equipment than those, is regarded as slightly inefficient than port of Tanjung Pelepas. It might be inferred that Singapore port relatively has a little slack in berth length and the number of cranes by more possessing 13% and 37% respectively compared to port of Tanjung Pelepas.

In terms of port efficiency according to nations, Singapore and Malaysia show had highest levels of port efficiency with the average efficiency value of 0.956 and 0.559 each. On the other hand, Myanmar and Cambodia had the lowest degrees of port efficiency with 0.091 and 0.073 respectively. This result may support decision making process for ODA recipient countries in maritime and port sector by providing objective data.

In conclusion, this study contributes to following aspects.

Firstly, acquiring ports data in ASEAN is quite difficult since there is little data port authorities published and they are reluctant to disclose it. Nonetheless, this study manages to obtain data from direct contact with port authority in Myanmar, academics in Thailand and so forth as well as Korea government reports. Secondly, inefficient ports can improve their port facilities and port performance by benchmarking DMUs, which have similar structure and size. In general, ASEAN ports has low port efficiency except for a few ports such as Singapore port, port of Tanjung Pelepas and port of Kota Kinabalu. Therefore, in order to improve maritime transport networks as an whole in ASEAN, for example, a port that has low levels of efficiency should benchmark efficient DMUs. This leads to facts that inefficient ports can plan to develop by benchmarking efficient ports as a blueprint for their future

Thirdly, port managers are capable of improving port operations according to information of slacks without constructing new port facilities. Fourthly, from the perspective of Korea, these results can be utilised to determine potential ports and countries for an international port development co-operation programme such as ODA with Korea by referencing objective data in order to help ASEAN to achieve better port networks by developing the infrastructures of ill-equipped ports. Lastly, to authors' the best knowledge, there is few research on analysing container port efficiency in ASEAN, while co-operation of the trade and maritime transport between Korea and ASEAN has being strengthened. Therefore, the current study can be viewed as the outset of port research in ASEAN.

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