Evaluation of Multipurpose Terminal Efficiency

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Abstract: ***Port efficiency plays an important element that associates with port competitiveness and performance. Due to that, having a good infrastructure is the key determinant of the port, and this includes a well-operated multipurpose terminal. The nexus of multipurpose terminal is crucial towards improving the port efficiency as it could intensify cargo traffic and meet customer requirements. Hence, this study intended to look at this issue by determining the efficiency of port technical competence by looking at the Kemaman Port Consortium (KPK) as the main focus. In this study, the bulk, chemical and liquid sections of the port from the period of 2015 to 2017 are analysed using Data Envelopment Analysis (DEA). The result shows that the East Wharf and Liquid Chemical Berth (LCB) sections are the most efficient section for Kemaman Port Consortium. It is expected that this study could be beneficial to terminal managers to further promote resource utilisation for a more robust development in operational efficiency.***

Keywords: Technical Efficiency, Multipurpose terminal, DEA

I. INTRODUCTION

As one of the biggest contributors on the regional development, port efficiency plays a crucial element that determine the port competitiveness and performance. Together with the growing international maritime traffic and rapid technological advance in the maritime sector, containerized and enhanced logistics activities, infrastructure is perhaps one of the key determinants of the port [15]. Due to the growing container traffic and high quality services required by shipping lines, a multipurpose terminal is compelled to improve port efficiency to boost up its relative advantage that will further intensify cargo traffic and meet customer requirements. Efficiency often means the speed and reliability of port terminal services. Container terminal efficiency is generally linked with productivity, performance and other factors related to the more productive parts of the organization. For instance, instead of knowing how ports utilize inputs to generate output levels, as well as the most efficient technology imbibed by multipurpose terminal, it is also fairly important to measure the multipurpose terminal efficiency [7].

The motivation of this study is to determine the efficiency of port technical competence on the improvement of Kemaman Port Consortium (KPK) competitiveness. This study analyzes the relative competitiveness and efficiency of three terminals at Kemaman Port Consortium which is located in critical geographic locations in the East Coast part of Peninsular Malaysia using DEA for the period between 2015 and 2017. The three-year period selected allows analysis of multi-purpose, chemical and multi-purpose divisions, especially in the Kemaman Port Consortium. The presence of the port consortium has now operated at maximum capacity for general cargo, liquids, and chemical and is likely to experience deterioration in operational efficiencies unless both capacity problems and terminal efficiency are solved.

II. LITERATURE REVIEW

II.I Efficiency

Efficiency is the ratio of actual output divided by input. It is also significant element in the production process, could be measured by parametric approaches applying econometric tools or non-parametric in regards to mathematical programming theory [4]. Measuring the efficiency, the actual attained or realized value of the objective function is compared against what is attainable at the frontier [16].

One of the main issues of port economics is lingering upon the efficiency, due to its strategic position as the main artery that links one country with other parts around the world. [10]. Relatively, port efficiency is measured by its ability to gain maximum output under a specific amount of input. Similarly, it can also be determined by the use of a given amount of output through the minimum amount of inputs, depending whether it is input or output oriented.

II. SELECTION OF VARIABLE

A robust and well regulated terminal infrastructure could play a remarkable role in the development of a country that will hence spur the nation's growth. In that case, it is important for the terminal to be perfectly equipped with necessary infrastructure to ensure that an efficient cargo handling operations is in place.

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In addition, it would prevent congestion, develop trade development, as well as building deep-sea container connections with countries that highly involved in the international trade.Due to the capacity of the port cannot be developed as soon as the demand increases [9], any potential capacity is finally exhausted and congestion episodes occur including those in the most efficient terminals. This requires a gradual, continuing and systematic effort in developing cargo capacity in the terminal. Terminal operators could be affected by the number of ship calls, as well as the size variability. This will focus on the flow of cargo to several terminals, thereby impacting the efficiency and terminal productivity cranes and adding pressure to the interior, which often gives an unfavourable impacts towards the congestion and the environment [24 and 11].

Some major multi-purpose terminal operations affect the versatility of terminal terminals, including vessel operation, loading / loading cranes handling, cargo handling with trucks, inspection operations, and cargo storage operations. From these operations, equipment and labor operations are key factors that determine the efficiency and effectiveness of multi-purpose terminals [14]. Due to the increased demand and limited storage space in most modern ports, nowadays, the most common storage approach is used [22]. Berths has a very large construction cost, and hence the number and length of the berth at multipurpose terminals is one of the most important strategic decisions that must be made at strategic stages and affected whole terminal operation if neglected [23].

The public berth system is used in multiple user terminals that process different carrier ships, and generally have longer docks and higher dock usage rates than specialized terminals. It is like the Kemaman Port Consortium which involves three parts such as bulk, chemical and liquid parts. When a vessel is moored at a berth, loading and unloading of cargo begins. Standard equipment designed for this task.

Table 1: Common Variables in Terminal Studies

Variables	Aspects	Terminals Section	Author
Output	Physical	Cargo throughput	[2]; [8]; [10]; [3] and [5]
	monetary	Annual avenue	No study has been taken in multipurpose terminal due to data confidential.
Input	Physical	Berth length (m) Quay crane (unit) Yard (ha) Terminal size (ha) Pipeline (km) Draft (m)	[22]; [21];[12] and [5]
	monetary	Salary payments Net value of fixed capital	No study has been taken in multipurpose terminal due to data confidential.

(Source: Rodseth et.al, 2015)

III. METHODOLOGY

In the case of DEA, two most typical classical models are usually applied, which is constant returns to scale (CRS or CCR), founded by Charnes, Cooper and Rhodes in 1978; and variables returns to scale (VRS or BCC) developed by Bankers, Charnes and Cooper in 1984. A non-parametric method is implied to measure relative efficiency of decision-making units (DMUs) that consists of many inputs and outputs [6] and [1]. By assuming all weights are fixed, a mathematical equation can be represented as follows [17]:

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

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 ≤ 1.

where

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

Equation for efficiency

CCR

$$\max \theta_k$$

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

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

$$\lambda_k \geq 0$$

BCC constraint added

2-0

To give a better perception on the analysis conducted, Figure 1 below shows how efficiency is measured for each unit

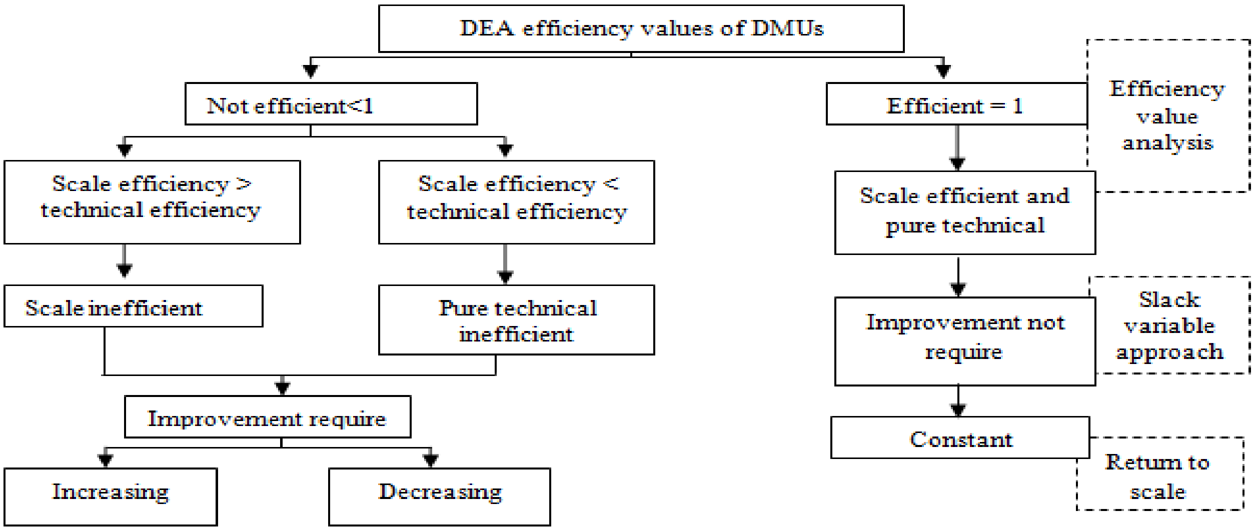

Figure 1: Summary of DEA efficiency
(Source: Song et al., 2012)

III.I STEPS OF ANALYSIS

In determining the performance of terminal efficiency, it involves the process of retrieving information, collecting data and analyzing critical point data at the terminal. This study involved three terminal sections at Kemaman Port Consortium and data selection was taken from 2015 until 2017. In this case, output-oriented DEA methods were also used as it was a multipurpose terminal. The steps of analysis is shown in Figure 2.

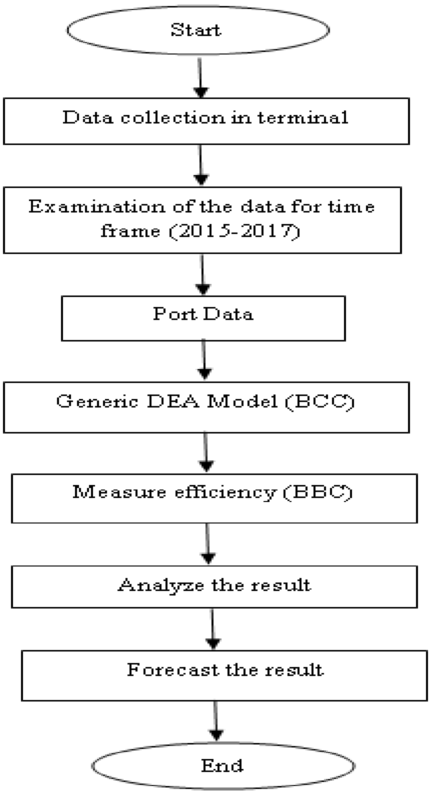

Figure 2: Flow Chart of Research Design

IV. RESULT FINDINGS AND INTERPRETATION

This study has been carried out to measure the efficiency of multipurpose terminal by accessing their output oriented with cargo throughput. The data were collected from three section multipurpose terminal authorities and also terminal operators. The variables were identified through literature review and judgement based on the characteristics of the terminal sections. Table 2 shows the descriptive statistics of input and output variables.

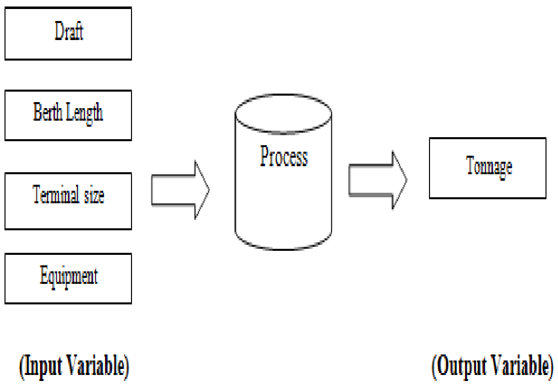

Figure 3: Framework of the Data Selection

Table 2: Input and output variables of fishing terminals

	Max	Min	Average	Std. Deviation
Berth Length	648	240	466	169.4462
Draught	16.4	16.4	16.4	0
Berth Capacity	6.85	2.6	5.35	1.94722
Yard	15000	4000	8306.667	4797.37
Tonnage	2622814	820579	1809462	622729.1

IV.I Correlation between Input and Output Variables

The correlation between inputs and outputs variable is shown in Table 3. For example, the correlation coefficient of draught with other input variables is 0 and signifies that there is no linear relationship between the variables. The correlation coefficient of terminal section indicates high correlation between berth length (BL), yard and berth capacity (BC). The correlation between berth length and yard is close with zero, indicated that the linear correlation is very weak. The correlation results with linear relationship ranking were summarizes in Table 3 and Table 4.

Table 3: Correlation between inputs and outputs variables

	Berth Length	Draught	Berth Capacity	Yard	Tonnage
Berth Length	1	0	0.959239	0.020536	-0.238548
Draught	0	1	0	0	0
Berth Capacity	0.959239	0	1	0.302234	-0.490056
Yard	0.020536	0	0.302234	1	-0.929105
Tonnage	-0.238548	0	-0.490056	-0.929105	1

Table 4: Correlation result with linear relationship ranking

	Berth Length	Draught	Berth Capacity	Yard	Tonnage
Berth Length	high	n/a	high	weak	low
Draught	n/a	high	n/a	n/a	n/a
Berth Capacity	high	n/a	high	medium	medium
Yard	weak	n/a	medium	high	high
Tonnage	low	n/a	medium	high	high

IV.II Technical efficiency of Multipurpose Terminals

Using DEA-BCCO model measured technical efficiency of multipurpose terminals for the year 2015, 2016 and 2017 respectively. The results of efficiency are shown in Table 5.

The score of 1 signifies "efficient" terminal sections while less than that indicates inefficient terminal sections. Based on BCCO findings, the analysis shows that only 2 terminal sections were efficient, which approximately 66.66% over the analyzed period. It is obvious that 33.34% of the terminal sections are inefficient over the analysed period.

Table 5: Efficiency result of using DEA-BCCO

No	Year	Terminal Section	Efficiency Score		Rank
1	2015	East Wharf	0.950189	Inefficient	3
2	2015	West Wharf	0.475112	Inefficient	7
3	2015	Liquid Chemical Berth (LCB)	1	Efficient	1
4	2016	East Wharf	1	Efficient	1
5	2016	West Wharf	0.322247	Inefficient	8
6	2016	Liquid Chemical Berth (LCB)	0.813285	Inefficient	5
7	2017	East Wharf	0.923911	Inefficient	4
8	2017	West Wharf	0.312862	Inefficient	9
9	2017	Liquid Chemical Berth (LCB)	0.792618	Inefficient	6

For the year 2017, all terminals section was inefficient with the score less than 1 but greater than 0. East Wharf terminal is considered close to the efficient frontier with score 0.923911 while other terminal like West Wharf and Liquid Chemical Berth (LCB) is 0.312862 and 0.792618 respectively. In 2015, only one terminal section is efficient, which is Liquid Chemical Berth (LCB), while the rest are identified as inefficient with scores of 0.950189 and 0.475112 respectively. During the analyzed period, West Wharf found as the lower efficiency score of 0.322247 in year 2016.

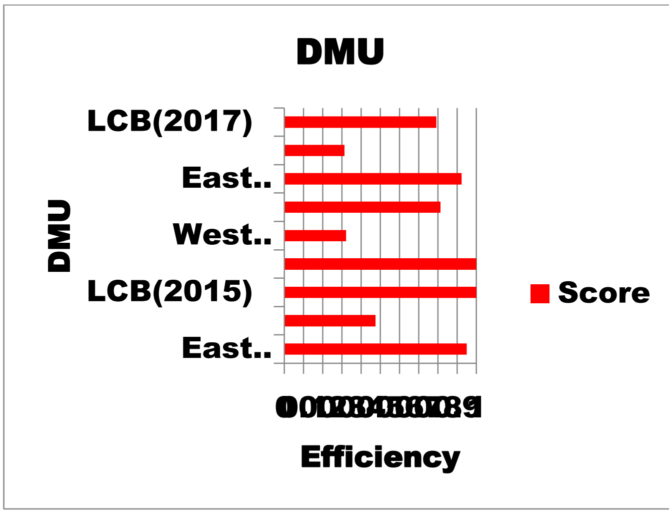

Figure 4: Efficiency of multipurpose terminal for year 2015 to 2017

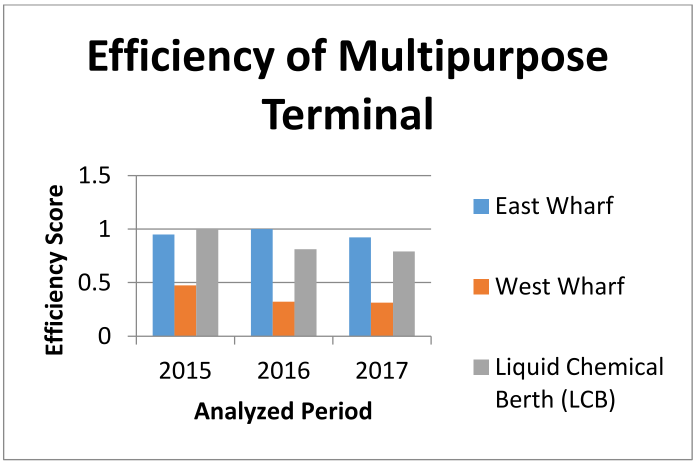

Figure 5: Efficiency of multipurpose terminal for year 2015 to 2017

IV.III REFERENCES SET OF BEST PRACTICE

Efficient terminal section of multipurpose terminal is called peers of benchmarks. The benchmarks are compiled through DEA computations. For the inefficient fishing terminal, the reference set of best practice provide information on which fishing terminal have to set as their referent in order to be efficient. On the other hand, the reference set shows large numbers of inefficient fishing terminals, as well as their scores.

Table 6: Benchmarks for input-oriented CCR model

No.	DMU	Score	Reference Set
1	East Wharf (2015)	0.950189	East Wharf (2016)
2	West Wharf (2015)	0.475112	LCB (2015)

3	LCB (2015)	1	LCB (2015)
4	East Wharf (2016)	1	East Wharf (2016)
5	West Wharf (2016)	0.322247	LCB (2015)
6	LCB (2016)	0.813285	LCB (2015)
7	East Wharf (2017)	0.923911	East Wharf (2016)
8	West Wharf (2017)	0.312862	LCB (2015)
9	LCB (2017)	0.792618	LCB (2015)

Table 7: Reference set of best practice to other DMU

Reference	Frequency to other DMU
LCB (2015)	5
East Wharf (2016)	2

The efficient fishing terminals may consider themselves to be their own benchmarks. For example, the benchmark for LCB (2015) is LCB (2015) and for East Wharf (2016) is East Wharf (2016). Table 7 present the frequency of best practice to other DMUs. Under the CRS assumption, the most frequent terminal section that is used as a benchmark by inefficient terminals is LCB (2015) in the year of 2015. Hence, it is identified as the peer for 2 inefficient fishing terminals.Hence, it is identified as the peer for 2 inefficient terminals section. This result is quite surprising, yet reasonable. West Wharf terminal are able to utilized minimum input for a given output, where their inputs are relatively small compare to other terminals.

IV.IV SLACK VARIABLE ANALYSIS

Slack variable analysis can be used to assist each inefficient terminal section to become efficient, by minimising the input in order to yield expected output efficiently. The analysis indicated that and Liquid Chemical Berth (LCB) terminal in year 2015 and East Wharf terminal in year 2016 had been comparatively efficient. Their productivity ratios are realistic and their input resources utilization was applied efficiently. The constraint is binding when a slack variable associated with a constraint is 0 which means the constraint restricts the possible changes of the point. If the constraint is non-binding, the constraint does not restrict the possible changes of the point. The terminal sections like East Wharf was inefficient due to inappropriate application of input resources – excess amount of resources utilized (refer to table 8). East Wharf can improve its efficiency or reduce its inefficiency proportionately, by reducing its inputs.

Table 8: Slack variable analysis result for inefficient fishing terminals

	East Wharf (2015)	West Wharf (2015)	West Wharf (2016)	LCB (2016)	East Wharf (2017)	West Wharf (2017)	LCB (2017)
Excess BL	0	270	270	0	0	2700	0
Excess D	0	0	0	0	0	0	0
Excess BC	0	4	4	0	0	4	0
Excess Yard	0	9080	9080	0	0	9080	0
Shortage T	0	0	0	0	0	0	0

V. CONCLUSION

It is undeniable that the globalisation has changed the pattern and need for a better role for transportation. Looking at this trend, multipurpose terminal could lead to a massive contribution due to its numerous economic and technical advantages for the port development. Multipurpose terminal has greatly improved port production performance as a consequence of its ability to attract shipping industry and promote a better port handling systems, thus enhancing port productivity. Looking at its potential, this study provides a measurement of efficiency of multipurpose terminal of the port by focusing at the Kemaman Port Consortium. In other words, this study intends to measure the impacts of terminal efficiency on the operational performance, providing the linkages to the best terminal service.

This study focuses on three sections of terminals namely, East Wharf, West Wharf and Liquid Chemical Berth at Kemaman Port Consortium from the year 2015 to 2017; measuring for their efficiency performance by looking at their index as well as slack variables analysis value. Based on the findings yielded from the BCCO analysis, two terminals have been found as efficient with West Wharf is regarded as the most efficient terminal. The most notable issue related to the finding could be due to the lack of output production that had affect the efficiency of the terminal, as well as the "fixed number of input" for the production. In addition, the findings from the BCCO also shows that efficiency values tend to fluctuate over time for both East Wharf and Liquid Chemical Berth (LCB) terminals. Interestingly, as for the slack variable analysis, a rather opposite finding is shown with West Wharf is found to be inefficient due to the over-utilized of input and insufficient output production. It is therefore suggested that the West Wharf terminals shall reduce the surplus variables such as berth length and yard in order to achieve the efficiency level in the future.To sum up, by tapping onto the capability of the multipurpose terminal in serving the port performance, it would allow related parties and stakeholders to impart necessary adjustment to further enhance the terminal performance.

In addition, this study provides an avenue that could be used to furnish the existing studies towards the betterment of the port performance.

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