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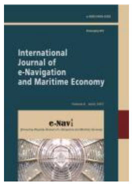

Original article

A Comparative Analysis on Operational Efficiency of Container Terminals by Basic and Malmquist DEA Models: A case of Haiphong Port

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Abstract

Port operational efficiency is considered as one of the most important competitive factors and plays a critical role in the port development all over the world, especially container ports. Haiphong Port, which is in the northern of Vietnam, is planned to become one of the national and regional ports. To do this objective, it is important to analyse the operational efficiency of its container terminals. The paper aims to comparatively analyse the operational efficiency of 16 container terminals in Haiphong Port from 2016 to 2022 by basic and Malmquist DEA models. With 112 observations collected and calculated in R software, DEA models have five inputs (container yard area, number of quay crane, berth draft, berth length, labour force) and one output (annual cargo throughput). Consequently, Hai An, Tan Vu, and Vip Greenport are more efficient terminals over the 7-year period, whereas Transvina and MIPEC have lower efficiency. Paper contributions are the literature review about port operational efficiency and references to propose resolutions in next author's research as well as masterplans to develop Vietnam seaport's system. Besides, the limitations are discussed as the number of observations and environmental factors in ports.

Keywords: operational efficiency, container terminal, data envelopment analysis, Haiphong Port.

https://doi.org/10.52820/j.enavi.2023.21.009

1. Introduction

"Seaport" is one of the most popular terminologies when mentioning to maritime logistics. Seaports are much more different than themselves in few centuries ago and their importance is undeniable in the modern world. In the very first day, traditional definitions of seaports limit their functions as a combination of dams and allow boats to stay (Hlali and Hammani, 2017). Through dozen decades, spreader ones developed with various functions. Branch (1986, pp. 1) defines the basic function of seaports is to provide a shelter for ships and handling activities. Others focus more on the economic corner of seaports, which emphasizes the necessary of activities related to handling, forwarding, domestic transportation for commodities transported by the sea from supplies to final customers (Commission of the European Communities, 1986, pp. 5; Bauchet, 1992). As a new turning point, Talley (2009, pp. 1) states seaports include terminals. In a perspective of supply chain, seaports are as a node in flows between maritime and domestic transport networks (Park et al., 2010, pp. 2; Sorgenfrei, 2013, pp. 70). With the same opinion, seaports are considered as a trade facilitator (Veenstra, 2015, pp. 13). Thereby, seaports play a vital role as crucial nodes in the global supply chain (Le and Nguyen, 2013, pp. 72).

In the tendency of global containerization, a variety of definitions of container seaports or terminals are rapidly flourished. Robert (2004, pp. 126) implies that container seaports are an objective development by periods, functioning as a place to transfer modes of transportation. Later, Steenken et al. (2005, pp. 12) proves the main reason why container ports or terminals establish is upon to their designs and equipment, while it is a statement that a port or terminal is determined as container one when it often serves at least 50 percent of the total handling goods (Sorgenfrei, 2013, pp. 74). Although there is an existence of different definitions of container seaports or terminals, a common clue is that they are a communicative system among parties, stakeholders, a designed area for activities related to containerized goods and intermodal transportation (World Bank, 2007a, pp. 367; Gunther and Kim, 2007, pp. 7; Talley, 2009, pp. 34; Guldogan, 2011, pp. 2; Ullrich and Baumert, 2018, pp. 141; Ha, 2020, pp. 13; Nguyen and Mai, 2020, pp. 82).

In the non-stop development of international trade, maritime logistics, and the blooming expansion of containerization, it is crucial that the growth of the operational efficiency needs to be an indispensably internal motive of container ports or terminals. The operational efficiency is defined as an important indicator to assess the overall quality of a port as well as its activities operated (Veenstra, 2015, pp. 13; Wang et al., 2003, pp. 705; Lin and Tseng, 2005, pp. 593; Wang et al., 2021, pp. 2; Kennedy et al., 2011, pp. 392). Additionally, the port operational efficiency is reflected by available resources (Wang and Cullinane, 2006, pp. 258; Talley, 2009, pp. 35; Burns, 2015, pp. 27; Pham, 2022; Nguyen et al., 2019; Nguyen et al., 2021). It means they must have highly operational efficiency to get higher competitive advantages and sufficiently potential prospects.

In Vietnam, the seaport system has gotten improvements about capacity and service quality. In an official statistic, there was a steady growth in port throughputs in recent years, including seaports and inland waterway ports. Figure 1 shows the comparison among total annual port throughputs, including seaports and inland waterway ports.

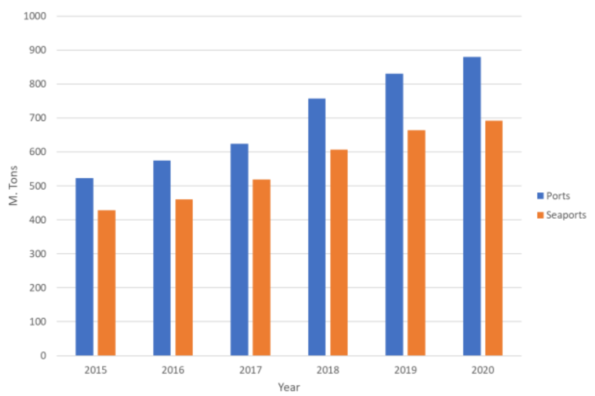

Figure 1. Vietnam's port throughputs 2015-2020.
Source: General Statistics Office (2021).

Noticeably, in a general masterplan of developing

Vietnam seaports' system, Haiphong Port belongs to Group 1 - a special port due to a high advantage of connecting to nearby neighbourhoods, regions, and nations by a large network consisting of various modes of transportation. It means this port has sufficient ability to serve high vessel calling, deadweight, and massive quantities of cargoes, especially containerized ones. Recently, Haiphong Port operated a lot of container terminals with high total throughputs, approximately 3.8 million TEUs (Vietnam Seaports Association, 2021), equivalent to nearly 20 percent of the national throughput. Until now, Haiphong Port is composed of 16 operating container terminals. Figure 2 shows the geographical location of each these terminals in Haiphong Port.

Figure 2. The layout of Haiphong Port.

Source: Le (2023, pp. 299).

Confronting opportunities and challenges when Vietnam's government concentrates on attend a lot of bilateral and multilateral commissions, non-profit, non-governmental organizations, Haiphong Port needs to stimulate operational efficiency of its container terminals to be in the deserved position of a special port. The goal of the paper is to comparatively analyse the operational efficiency of 16 container terminals in Haiphong Port between 2016 and 2022 to have a thorough glance of effective ones, which could be a reference for port operators, officers, policymakers to propose some renovative resolutions or orientations. In this paper, I decided to use basic and Malmquist DEA models with the total observations of 112 by software R. I consider lots of research on the operational efficiency of Haiphong Port, however, its latest situation is not updated, especially after the massive impact of global epidemic, COVID-19. Following this, I constructed the paper with main sessions as follows: A review literature or theoretical background of port operational efficiency will be showed in Section 2; Section 3 will reflect my methodology, basic and Malmquist DEA models; The result of the paper is going to be supplied in Section 4; and the last section will be my discussion of the above result, future research, and limitations.

2. Literature review

Mentioning to research on port operational efficiency, there have been not a general definition yet. Operational efficiency, however, is usually referred to several KPIs (Key Performance Indicators). The usage of which KPI is upon to different business goals given by port operators, but just some certain ones is often used in research to evaluate it.

Port efficiency is a quality measurement of ports (Veenstra, 2015, pp. 13). Chung states port operational efficiency is often measured by the speed of good handling, vessel turnaround time, and port inventory time (World Bank, pp. 1). Meanwhile, Wang et al. (2003, pp. 705) proves that port operational efficiency is the same as the business or production one, and they are all showed by the most important indicator, port throughput. It is also charted by port callings and the number of handling containers (Barros and Athanassiou, 2004, pp. 305; Nguyen et al., 2021, pp. 332). Moreover, it is demonstrated that due to the complexity of operational activities in ports or terminals, the efficiency deems to be most relevant to service quality, management, finance, and revenue, or profit (Lin and Tseng, 2005, pp. 593; Wang et al., 2021, pp. 2). Facing to the survival, competition and development, the operational efficiency is an essential part that needs to be enhanced (Cullinane and Wang, 2007, pp. 518) by maximizing the container throughput with available resources (Wang and Cullinane, 2006, pp. 258; Talley, 2009, pp. 35). Besides, there is an existence of different glances or corners in some other research. Kennedy et al. (2011, pp. 392) determines port operational efficiency by the quality of handling service and domestic transportation. With Burns (2015, pp. 27), it is partly reflected by the labour force, technology, equipment, procedure, or supply chain. Ha (2017, pp. 120; 2020, pp. 31) mentions that it can be calculated by port productivity, the satisfaction of container vessel owners, shippers, and forwarders. In the same period, Vu (2020), and Nguyen and Mai (2020) evaluate it by the ratio of direct forwarding, handling, and working productivity, storage factor, and inventory time. While Wang et al. (2022, pp. 1385) considers port connectivity or operating functions are effective factors, Pham (2022) deeply sees it by port productivity in terms of berth, yard, and gate.

Table 1. Summary of some research on port operational efficiency.

Author(s)	Data	Method(s)	Input(s)	Output(s)
Roll and Hayuth (1993)	20 ports over the world	DEA	Capital, Labor, Cargo uniformity	Port calling, Cargo throughput, Customers' satisfaction, Service level
Wang et al. (2003)	57 container ports over the world in 1999	CCR DEA model, BCC DEA model, FDH	Quay length, Port area, The number of quay and yard crane, and straddle carrier	Cargo throughput
Lin And Tseng (2005)	27 international container ports from 1999 to 2002	CCR DEA model, BCC DEA model, SFA with Cobb-Douglas production function, SFA with Translog production function	The number of quay crane, yard handling equipment, Quay length, Yard area	Annual cargo throughput
Nguyen et al. (2019)	26 container terminals throughout Vietnam from 2013 to 2017	Malmquist DEA model	Berth length, The number of quay crane, industrial park, Yard area, Population	Container throughput, Vessel call
Wang et al. (2021)	14 Vietnam terminals from 2015 to 2020	Malmquist DEA model, Epsilon-based measurement DEA model	Asset, Trustworthiness, Operational cost, Equity	Revenue, Net profit
Nguyen et al. (2021)	10 container terminals in Southern Vietnam from 2017 to 2019	Malmquist DEA model, Slack-based DEA model, Undesirable output DEA model	Quay crane productivity and intensity, Berth length and depth	Port calling, Handling moves, Elapsed time

Source: Le (2023, pp. 301).

Considerably, lots of methods are used to analyse or evaluate port operational efficiency and one of the most popular one is DEA (Data Envelopment Analysis). Basically, DEA allows users to measure effective scores of ports in a relative way, which means comparing their effectiveness at the same time, with multiple inputs and outputs. Table 1 is my summary of some research related to port operational efficiency. A flourishing boom of research on port operational efficiency by DEA model has been happening since Roll and Hayuth (1993). This research gives theoretical background of DEA method to apply 20 ports over the world. It is a clear basement to apply DEA to port efficiency, however, it is not practically meaningful due to its data created hypothetically. Wang et al. (2003) combines two DEA models along with another method to compare the effectiveness of 57 container ports over the world in 1999. The combination allows authors to find where the lack of port effectiveness happens with the ratio between inputs and outputs. However, it exists an objective consideration due to the analysis of only-one-year data. Lin and Tseng (2005) also combine many DEA and other models to assess the efficiency of 27 international container ports from 1999 to 2002. That is likely to detect reasons of the lacking efficiency. The focus of this research is to assess in an extensive range, so it is not appropriate to the local development. Nguyen et al. (2019), and Wang et al. (2021) focus more on one nation to evaluate terminals from 2015 to 2020 by DEA models. At the same time, Nguyen et al. (2021) limits the research range to 10 container terminals in Southern Vietnam from 2017 to 2019. Also, Hang et al. (2021) glances at container terminals in Haiphong Port from 2010 to 2019.

Otherwise, it is demonstrated that many similar papers with different DEA models have been existed to evaluate port operational efficiencies, not mention to research in a certain area, for instance, Haiphong Port, but its necessity is not removed due to some reasons. First, as mentioned above, Haiphong Port will become a special port. There are many ports established throughout Vietnam's long coastal line, but only 02 ones, Haiphong Port and Cat Lai Port, account for approximately 90 percent of the national throughput in fact, and the former makes up about a third of that. Hence, it is necessary that lots of research should focus thoroughly on its local development to accelerate the national economy. Second, despite the massive research on Haiphong Port done, newly situational cases are not updated, especially after the enormous impact of COVID-19 pandemic on Vietnam maritime industry in 2020. Therefore, it can be clearly revealed that a research gap is a requirement of analysing the operational efficiency in the local range with different DEA models along with new data collections. To fill this gap, I decided to collect a primary dataset of 16 operating container terminals in Haiphong Port in recent 7-year period and combines basic and Malmquist DEA models to analyse comparatively.

3. Methodology

Basically, DEA or Data Envelopment Analysis method allows users to flexibly combine multiple inputs and outputs without internal factors to analyze DMUs (Decision-Making Units) as black boxes (Akbarian, 2021; Li and Wang, 2015) or the form of PPF (Production Possibility Frontier) (Nguyen and Quach, 2021). It is a non-parametric mathematical technique used widely to evaluate the effectiveness of DMUs.

Due to the above outstanding feature, the method is developed with lots of new models, in which, 02 standard models, CCR DEA and BCC DEA (Charnes et al., 1978; Banker et al., 1984; Zhang and Li, 2020). In DEA method, normally, the first step is to determine the input and output variables (x_{1k}, …, x_{mk}), (y_{1k}, …, y_{qk}) with proportional weights (v_1, …, v_m), (u_1, …, u_q) respectively. Then, each DMU_k (k = 1, …, n) represents an efficiency score resulted from the combination between variables and weights (Zhang and Li, 2020).

The CCR model is performed as follows:

Inputs: $$max \frac{\sum_{r=1}^{q} u_r y_{rk}}{\sum_{i=1}^{m} v_i x_{ik}} \quad (1)$$

Subject to

$$\frac{\sum_{r=1}^{q} u_r y_{rk}}{\sum_{i=1}^{m} v_i x_{ik}} \leq 1 \;\; (k = 1, \dots, n),\; x_{ik} \geq 0,\; y_{rk} \geq 0 \quad (2)$$

$$u_r \geq 0 \;\; (r = 1, \dots, q), v_i \geq 0 \;\; (i = 1, \dots, m) \quad (3)$$

Outputs: $min \frac{\sum_{i=1}^{m} v_i x_{ik}}{\sum_{r=1}^{q} u_r y_{rk}}$ (4)

Subject to

$$\frac{\sum_{i=1}^{m} v_i x_{ik}}{\sum_{r=1}^{q} u_r y_{rk}} \leq 1 \;\; (k = 1, \dots, n),\; x_{ik} \geq 0,\; y_{rk} \geq 0 \quad (5)$$

$$u_r \geq 0 \;\; (r = 1, \dots, q), v_i \geq 0 \;\; (i = 1, \dots, m) \quad (6)$$

The BCC model is performed as follows:

Inputs: $max \sum_{r=1}^{q} u_r y_{rk} + \mu_0$ (7)

Subject to

$$\sum_{r=1}^{q} u_r y_{rk} - \sum_{i=1}^{m} v_i x_{ik} \leq 0 \;\; (k = 1, \dots, n) \quad (8)$$

$$\sum_{i=1}^{m} v_i x_{ik} = 1 \quad (9)$$

$u_r \geq 0 \;\; (r = 1, \dots, q), v_i \geq 0 \;\; (i = 1, \dots, m), \mu_0 \in R$(10)

Outputs: $max \sum_{i=1}^{m} v_i x_{ik} + v_0$ (11)

Subject to

$$\sum_{r=1}^{q} u_r y_{rk} - \sum_{i=1}^{m} v_i x_{ik} + v_0 \leq 0 \;\; (k = 1, \dots, n) \quad (12)$$

$$\sum_{r=1}^{q} u_r y_{rk} = 1 \quad (13)$$

$u_r \geq 0 \;\; (r = 1, \dots, q), v_i \geq 0 \;\; (i = 1, \dots, m), v_0 \in R$(14)

Where μ_0 and v_0 are free variables.

Malmquist DEA model uses MPI (Malmquist Productivity Indicator) to evaluate the efficiency of a DMU whether if it increases or decreases over time. MPI is first introduced by Malmquist (1953), as a combination of two components, “Catch-up” and “Frontier-shift”. While the former refers to the efficiency change of a DMU, the latter shows technology innovation or regression between two time periods (Tone, 2004, pp. 204). Similarly, compared to the basic model, steps are the same, however, we need to deal with DMU_k (k = 1, …, n) through $(x_k, y_k)^1$ and $(x_k, y_k)^2$ in period 1 and 2 respectively, where $x_k \geq 0$ and $y_k \geq 0$, instead of the relationship with weight vectors. MPI is performed as follows:

MPI = (Catch-up) x (Frontier-shift)

$$= \left(\frac{E^2(x_k,y_k)^2}{E^1(x_k,y_k)^1}\right) x \left[\left(\frac{E^1(x_k,y_k)^1}{E^2(x_k,y_k)^1}\right) x \left(\frac{E^1(x_k,y_k)^2}{E^2(x_k,y_k)^2}\right)\right]^{1/2} \quad (15)$$

Where $E^2(x_k, y_k)^1$ is the efficiency score of DMU_k in period 1, calculated in the frontier technology in period 2, and vice versa.

The values of MPI and its components, “Catch-up” and “Frontier-shift”, can be various. If they have the value of 1, it shows the stability in productivity of a DMU between two time periods. Meanwhile, if their value above or under 1, it reveals that there is an improvement or a regression in the DMU productivity over time.

In this study, after collecting the primary dataset through direct visits, observations, discussions with staff, managers, and operators in Haiphong Port in many years, I choose inputs and outputs for DEA models by the empirical and literature review. Then, I use Pearson’s and Spearman’s correlation test to calculate the statistical meaning between each couple of variables and eliminate the unconditional one before continuing to use CCR, BCC, Malmquist DEA models in turns to compare scores from 2016 to 2022, analyzing them. Procedures are all done by R software.

Following this, selected 16 container terminals are Nam Hai (1), Doan Xa (2), Transvina (3), Green Port (4), Chua Ve (5), Tan Cang 128 (6), Tan Cang 189 (7), Hai An (8), Dinh Vu (9), PTSC (10), Tan Vu (11), Nam Hai Dinh Vu (12), Vip Greenport (13), Nam Dinh Vu (14), TC-HICT (15), MIPEC (16). Inputs and outputs for DEA models are container yard area (X1), number of quay crane (X2), berth draft (X3), berth length (X4), labor force (X5), and annual cargo throughput (Y) respectively. Table 2 illustrates statistical description of the dataset with the total of 112 observations. Clearly, minimum values of all variables are 0.00. Large spaces between minimum and maximum can be easily seen in X1, X4, X5, Y due to remarkable values of means and standard deviations, while the opposite is true for X2 and X3.

Table 2. The dataset statistical description.

Criterion	X1	X2	X3	X4	X5	Y
Minimum	0.00 m^2	0.00 units	0.00 m	0.00 m	0.00 labor	0.00 thousand TEUs
Maximum	562.50 m^2	15.00 units	14.00 m	980.00 m	980.00 labor	1,066.00 thousand TEUs
Mean	157.30 m^2	4.92 units	8.35 m	375.00 m	262.90 labor	307.53 thousand TEUs
Standard deviation	144.49 m^2	3.61 units	2.63 m	263.46 m	207.20 labor	271.71 thousand TEUs

Source: Le (2023, pp. 299).

4. Results

4.1. Correlation test

In this study, I tested Pearson's and Spearman's correlation coefficient between five inputs and only one output with 95 percent confidence interval. Table 3 supplies Pearson's and Spearman's correlation coefficient. In general, chosen variables are all statistically significant due to p-values under 0.05 and they all have the positive correlation. Most correlation coefficients are between 0.50 and 0.70, which means being in the moderate group, whereas X5's ones are under 0.50 with the low correlation. Noticeably, X2's and X3's correlation coefficients are little different. The highest value of 0.73 is recorded by Pearson's correlation coefficient in X2, and it is the high correlation. Therefore, all inputs and outputs are conditional enough for DEA models to comparatively analyze the operational efficiency of 16 container terminals in Haiphong Port.

4.2. CCR and BCC DEA analysis

Upon to chosen inputs and outputs, I calculated efficiency scores of 16 container terminals in Haiphong Port in two basic DEA models, CCR and BCC, by R software. Table 4 figures efficiency scores of 16 container terminals in Haiphong Port every year in the period. Then, to rank the effectiveness of 16 these container terminals in order, I calculated the average score of 7 years for every DMU in two models. Overall, most efficiency scores are the same in two models. Some terminals experienced massive decreases in the efficiency from 2016 to 2022. These are Nam Hai, Doan Xa, Transvina, Green Port, Tan Cang 189 and PTSC. By contrast, significant increases in the efficiency were witnessed by Chua Ve, Hai An, Tan Vu, Nam Hai Dinh Vu, Vip Greenport, Nam Dinh Vu, TC-HICT. The remaining ones only saw a little change in the period.

Table 3. Pearson's and Spearman's correlation coefficient.

	Correlation coefficient	X1	X2	X3	X4	X5
Pearson	Y	0.69	0.73	0.46	0.66	0.41
	P-value	2.20e-16	2.20e-16	2.76e-07	4.17e-15	8.24e-06
Spearman	Y	0.57	0.64	0.61	0.63	0.42
	P-value	3.55e-11	2.27e-14	5.91e-13	1.57e-13	3.77e-06

Compared to average scores, the most effective container terminal in Haiphong Port is Dinh Vu with the average score of 0.929, followed by Hai An terminal and Tan Vu terminal, 0.923 and 0.895 respectively. Meanwhile, the most ineffective one is MIPEC recorded in two DEA models with the average score of 0.030. Additionally, there is a little difference between two DEA models, which represents average scores of Tan Cang 189 and TC-HICT. Due to these differences, ranks of two these terminals are also distinct.

4.3. Malmquist DEA analysis

Like two basic models, I used chosen inputs and outputs to calculate MPI by R software. Table 5 represents MPIs as well as efficiency scores of 16 above container terminals. Accordingly, "MPI" is Malmquist Productivity Indicator, "Eff-change" and "Tech-change" show "Catch-up" and

“Frontier-shift”, whereas “CRS” and “VRS” illustrate the efficiency score measured with constant returns-to-scale and variable returns-to-scale respectively. For MPIs shown in table 5, they are average results of available values computed by R software. Following this, none of MPI is equal to 1. MPIs are mainly above 1, and it means that most terminals have higher efficiency than before. With MPI values under 1, it shows lower efficient terminals are Doan Xa, Transvina, Green Port, Chua Ve, Dinh Vu, PTSC.

Table 4. Average efficiency scores and ranks of 16 container terminals in Haiphong Port.

DMU		2016	2017	2018	2019	2020	2021	2022	Average	Rank
Nam Hai	CCR	0.951	0.296	0.374	0.556	0.389	0.481	0.570	0.517	8
	BCC	0.951	0.296	0.374	0.556	0.389	0.481	0.570	0.517	8
Doan Xa	CCR	0.869	0.199	0.156	0.148	0.011	0.000	0.000	0.198	14
	BCC	0.869	0.199	0.156	0.148	0.011	0.000	0.000	0.198	14
Transvina	CCR	0.544	0.281	0.322	0.073	0.032	0.000	0.000	0.179	15
	BCC	0.544	0.281	0.322	0.073	0.032	0.000	0.000	0.179	15
Green Port	CCR	1.000	0.905	0.857	0.775	0.721	0.863	0.889	0.859	5
	BCC	1.000	0.905	0.857	0.775	0.721	0.863	0.889	0.859	5
Chua Ve	CCR	0.000	0.000	0.000	0.448	0.591	0.500	0.355	0.271	13
	BCC	0.000	0.000	0.000	0.448	0.591	0.500	0.355	0.271	13
Tan Cang 128	CCR	0.316	0.412	0.237	0.409	0.242	0.332	0.360	0.330	12
	BCC	0.316	0.412	0.237	0.409	0.242	0.332	0.360	0.330	12
Tan Cang 189	CCR	0.526	0.000	0.493	0.371	0.455	0.471	0.475	0.399	9
	BCC	0.526	0.000	0.493	0.371	0.455	0.471	0.475	0.399	10
Hai An	CCR	0.918	0.877	0.926	0.934	0.825	0.980	1.000	0.923	2
	BCC	0.918	0.877	0.926	0.934	0.825	0.980	1.000	0.923	2
Dinh Vu	CCR	0.975	1.000	1.000	0.821	0.810	0.936	0.959	0.929	1
	BCC	0.975	1.000	1.000	0.821	0.810	0.936	0.959	0.929	1
PTSC	CCR	0.700	0.957	1.000	1.000	0.977	0.797	0.549	0.854	6
	BCC	0.700	0.957	1.000	1.000	0.977	0.797	0.549	0.854	6
Tan Vu	CCR	0.739	0.842	0.836	0.924	0.938	1.000	0.989	0.895	3
	BCC	0.739	0.842	0.836	0.924	0.938	1.000	0.989	0.895	3
Nam Hai Dinh Vu	CCR	0.733	1.000	0.894	0.717	0.839	0.865	0.864	0.844	7
	BCC	0.733	1.000	0.894	0.717	0.839	0.865	0.864	0.844	7
Vip Greenport	CCR	0.511	0.802	0.895	0.986	0.926	1.000	1.000	0.874	4
	BCC	0.511	0.802	0.895	0.986	0.926	1.000	1.000	0.874	4
Nam Dinh Vu	CCR	0.000	0.000	0.484	0.577	0.445	0.619	0.618	0.392	11
	BCC	0.000	0.000	0.484	0.577	0.445	0.619	0.618	0.392	11
TC-HICT	CCR	0.000	0.000	0.069	0.465	0.644	0.677	0.902	0.394	10
	BCC	0.000	0.000	0.069	0.465	0.644	0.677	1.000	0.408	9
MIPEC	CCR	0.000	0.000	0.000	0.000	0.024	0.093	0.094	0.030	16
	BCC	0.000	0.000	0.000	0.000	0.024	0.093	0.094	0.030	16

Table 5. Average MPI, efficiency scores and ranks of 16 container terminals in Haiphong Port.

DMU	MPI	Eff-change	Tech-change	CRS	Rank	VRS	Rank
Nam Hai	1.030	1.005	1.015	0.548	8	0.760	8
Doan Xa	0.509	0.517	0.987	0.218	14	0.645	11
Transvina	0.581	0.591	1.029	0.211	15	0.634	12
Green Port	0.981	1.000	0.981	1.000	1	1.000	1

Chua Ve	0.971	0.963	1.023	0.284	13	0.489	14
Tan Cang 128	1.109	1.038	1.048	0.358	12	0.647	10
Tan Cang 189	1.011	0.975	1.044	0.438	9	0.653	9
Hai An	1.043	1.000	1.043	1.000	1	1.000	1
Dinh Vu	0.995	0.995	0.999	0.959	5	0.977	6
PTSC	0.969	0.926	1.044	0.924	7	1.000	1
Tan Vu	1.083	1.000	1.083	1.000	1	1.000	1
Nam Hai Dinh Vu	1.032	0.992	1.050	0.926	6	0.952	7
Vip Greenport	1.131	1.009	1.118	0.993	4	0.993	5
Nam Dinh Vu	1.081	1.029	1.040	0.428	10	0.606	13
TC-HICT	2.598	2.442	1.059	0.425	11	0.445	15
MIPEC	2.404	2.275	1.032	0.031	16	0.429	16

Besides, the MPI's increase, or decrease depends on its components. For example, increasing MPI values of Nam Hai, Tan Cang 128, Vip Greenport, Nam Dinh Vu, TC-HICT, MIPEC are reflected by improvements in both efficiency and technology. By contrast, the depression in both efficiency and technology is responsible for drowning MPI values of Doan Xa, Dinh Vu.

There are many ranking differences in Malmquist DEA model with constant returns-to-scale in comparison to variable one. Green Port, Hai An, Tan Vu are the most efficient terminals in this model, however, it is noticeable that PTSC stands the seventh position in the model with constant returns-to-scale while it comes to the first rank with the other.

Moreover, in the light of prejudices, 04 first-ranking terminals in Table 5 (Green Port, Hai An, Tan Vu, PTSC) do not mean having same efficiencies. It is the fact that these ones operate in their distinct sizes, but they are determined as the most efficiently performing terminals opposed to others within limited individual inbound resources. In other words, these use available resources effectively, whereas others yet.

4.4. Comparison of CCR, BCC, and Malmquist models

To have clearer observations, I put ranks in chosen models side by side. Most terminal's efficiency scores are ranked similarly, except for Green Port, Dinh Vu, PTSC. In CCR and BCC models, Green Port has the fifth position whereas it stands the first or second position in Malmquist model, and the opposite is true for Dinh Vu. For PTSC, the first place is shown in Malmquist model with variable returns-to-scale, and other models noted it as the sixth or seventh one.

4.5. Reasons for the inefficiency

There are several causes to the operational inefficiency of some container terminals in Haiphong Port that could be suggested as follows:

- Asynchronous infrastructure: Most ports or terminals in Vietnam are usually allocated in an allowed area following to national and local masterplans, caused inefficiently initial design in facilities installation and transport network connectivity. The surplus or lack of operational facilities, the standardisation of the quay, berths, could deeply affect the overall performance of the port or terminal.

- Ineffective container yard operations: With limited given resources, a terminal operator always set up operational plans for activities. If available resources exceed its productivity, it could make the inefficient usage, especially in container yard that is an essential storage in export and import goods handling.

- Low labour force quality: Despite a mass of labours used in every terminal, their quality is not fit for the port productivity. Port operations require

the suitability of labour forces, regarding the quantity and quality. As a result, when the quantity outweighs the quality, it makes a sophisticated process of management and operations, not in direct proportion to the annual throughput.

5. Conclusions

In conclusion, my paper reviewed the literature of port operational efficiency and DEA methods applied for the comparison of the operational efficiency. The paper is to comparatively analyze the operational efficiency of 16 container terminals in Haiphong Port from 2016 to 2022 by some DEA models. As a result, it is found that Hai An, Tan Vu, and Vip Greenport are more efficient terminals over the 7-year period, whereas Transvina and MIPEC have lower efficiency.

The paper is as my contribution to port operational efficiency, especially container ports in Vietnam. The research result states some inefficiency reasons of container terminals, which might drive me in the next research on resolutions to deal with as well as could be a reference for policymakers and government officials to propose masterplans to develop Vietnam seaports' system. However, I also consider some paper limitations such as the number of observations or environmental factors in the international port development.

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Received **26 November 2023**

1st Revised **12 December 2023**

2nd Revised **21 December 2023**

Accepted **27 December 2023**