The Seybold Report

ISSN 1533-9211

MEASURING EFFICIENCY OF INDIAN PORTS THROUGH DATA ENVELOPMENT ANALYSIS: A COMPARATIVE ANALYSIS OF MUNDRA AND KANDLA PORT IN GUJARAT

Dr. JUSTIN JOHN STEPHEN [1] and Dr. PRAKASHCHANDRA PARMAR [2]

[1, 2] Assistant Professor, Department of Business Economics, The Maharaja Sayajirao University of Baroda, Gujarat.

Abstract

The purpose of the study is to evaluate the ownership structure of Mundra and Kandla seaports with a objective to compare the efficiency of these two ports over the period of 2017-2022. The data on various variables of inputs and output were collected from the port Management. The study applies data envelopment analysis with input orientation to calculate the relative efficiency score of Gujarat's most leading ports for the respective reference period. The investigation carried out both on singular aspects of individual port and on a cross sectional analysis of the port. The efficiency estimated on individual ports reveal that the Mundra Port has an average efficiency of 0.92 percent on reported periods. And the efficiency representation of the Mundra Port is consistent compared to its counterpart with 0.73 percent ofscore. As a result Mundra Port outperforms the Kandla Port. However the analysis of panel data reveals a fluxuation in these two ports efficiency, indicating that the result outcomes of cross-sectional data may bemisleading. It was also found that ports exhibiting a mixture of decreasing, increasing and contant returnedto scale. Moreover Data Envelopemnt Analysis results obtained for individual ports can be more reliable, because each single port could have its specific and unique contexts in place.

Keywords: Ownership Structure, Technical Efficiency, Data Envelopment Analysis

JEL Classification: C01, C33, O13, and Q43

I. INTRODUCTION

Assessing a firm's performance, whether it is evaluating successes against stated goals and objectives or the competition, is a fundamental notion for any business. Seaports are no exception, and performance canonly be assessed through comparison. Seaports are complicated businesses with diverse inputs and outputs, making direct comparisons between seemingly similar ports problematic. The many forms of port ownership and organisational systems worldwide further complicate the situation. Over the last two decades, ownership of one of the essential commerce entry points into any country, the ports, has shifted from national or municipal governments to private hands, either entirely or partially. This trend, known as privatisation, and because of its importance in international trade and business, port performance evaluationhas piqued the interest of policymakers, industry stakeholders, and scholars

Given that India is bordered on three sides by the sea, its economic growth depends on its seaports, whichhandle 90% of its export and import. In this regard, large ports play an essential part in the country's exportand import activities. India's biggest ports account for more than 75% of the country's total trade. The commodities are moved through the logistics chain, and logistics become crucial for trade competitiveness. As a result, monitoring port efficiency should be prioritised, and necessary efforts should be made to improve inefficient ports' performance. Efficiency analysis allows port owners and authorities to make better judgments about port development and operations. At the same time, it also enables port users to (particularly shipping lines) examine the relative competitiveness of ports and make better decisions aboutport usage.

Considering the preceding, this study investigates the issue of whether ownership influences the efficiencyof India's major ports. In the context of the above, this study will look at how the ownership structure of seaports in India has any relation to its performance based on the Data Envelopment Analysis (DEA) to assess the relative efficiency of a sample of ports – Mundra port and Kandla port, both located in the stateof Gujarat. Thus, the purpose of this study is to see if the claim that ownership pattern is a contributing factor to port efficiency is valid. To answer this question, during the study period 2017-2021, the current paper evaluated the operational efficiency of the two ports in India, as stated above. These two ports werechosen because they are both on India's west coast, on the Gulf of Kutch. They have equivalent catchmentregions and serve comparable hinterlands due to their geographical proximity. It is expected that the results of this paper will help serve as a guide for governments, port administrators, and port owners on the different ways in which they can structure their ports to lead to greater efficiency. The remainder of the research is organised as follows. The profiles of the two ports are described in section 2. The third part is devoted to a review of the literature. Section 4 describes the data sources and methodology. The results areprovided in section 5. Finally, section 6 brings the paper to a close.

2. PROFILES OF KANDLA AND MUNDRA PORT

Kandla Port

Kandla Port (also known as Deendayal Port) is a seaport in the public sector under the administrative superintendence of the Ministry of Shipping, Government of India, which has been functioning since the 1950s. The geographical location of this port is on the Gulf of Kutch. It is a natural port. It is India's largestbulk cargo port. The containers imported through Kandla Port in the Apr-Aug period of FY 2021-22 increased by 52.16% compared to FY 2020-21. The increase in import of Heavy melting Scrap and Steel Coils (15.71%) and Bitumen was the key reason behind this jump.

The gross revenue in the Apr-Aug period of FY 2021-22 increased by 163.03% compared to thecorresponding period of 2020-21; driven by an increase in import of edible oils, primarily Crude Palm Oil(+384%) and Soyabean Oil (+260%) as well as Chemicals like Ammonia (+215.27%) and Methanol (+332.52%).

The containers' export increased by 41.88% between April and August of this FY 2021-22 compared to 2020-21. The major commodities driving this surge are Steel Billets (+774.23% in terms of FOB Value) and Ceramic Glazed Tiles (+306.16% in FOB Value). 33.88% increase in the number of Bills of entry in Apr-Aug period of current FY 2021-22 compared to FY 2020-21. Compared to the corresponding period of 2019-20, there's a slight downtick of 6.18% in the number of BEs in 2021-22. Still, overall revenue hasgone up by 90.04% due to the higher import volume of Edible Oils and chemicals like Acrylonitrile, Anhydrous Ammonia, and Methanol. There has been a 93% increase in the number of shipping bills in theApr-Aug period of current FY 2021-22 compared to the corresponding period of previous FY 2020-21. The higher count is attributed to an increase in the export of commodities like Indian White Sugar (+86% of FOB Value), Cup Brand Indian Basmati Rice (+375.49%), Sharbati Golden Shell Rice (+375.49%), Steel Billets (+774.23%) and Ceramic Glazed Tiles (+306.16%).

Mundra Port

APSEZ Limited, Mundra (also known as Mundra Port) is a multisector SEZ and the country's largest privately developed port. It is located in the Northern Gulf of Kutch, Gujarat, on India's western coast, andhas an area of 100 square kilometers. It is a year-round port. It is also a natural port, like Kandla. The port'scommercial activities began in October 2001. Dry, Bulk, Break Bulk, Liquid, Crude Oil, Project Cargo, Cars, and Containers are among the cargo types handled by APSEZ Limited, Mundra. Mundra port has oneof the deepest draughts among India's ports. Twelve multi-purpose berths, nine container berths, 2 SBM for crude oil import, four coal import berths, and Ro-Ro facilities for vehicle traffic are all available at theport. Mundra port's West Basin is likely the world's largest coal import terminal. Mundra port has 30 activeberths for dry bulk, break bulk, project cargo, crude oil, LPG, LNG, container cargo, and liquid cargo. Theautomated terminal has a capacity of 4.67 lakh KL and contains 100 tanks. The Mundra port's dedicated Container Terminals have a capacity of more than 5.8 million TEUs. There is also a Pure Car Carrier/ PureCar Truck Carrier (PCC / PCTC) berth with adequate parking space at this port. There is a pre-dispatch yard with a capacity of 2000 cars and a buffer yard with a capacity of 2000 cars.

Mundra's APSEZ Limited operates a 64-kilometer private rail network that has been expanded to accommodate double-stacked container trains. APSEZ Limited, Mundra, has a 380-kilometer coverage area in India's northern hinterland. The NH 8A, NH 15, and other state highways connect well to Mundra port. Mundra's APSEZ Limited also has a functioning airport to handle private jets. Mundra is also well connected to two commercial airports located within 60 kilometers of the city. Mundra port's dry cargo facility can handle any form of dry cargo. Import freight may be handled at 1500 TPH on a 3.6 km long import conveyor system. The Mundra port's Agri-Complex can handle 2 MMTPA and has rake handling facilities. A Fertilizer Cargo Complex is also located at this port. There is a mechanical method for bagging and loading fertiliser bags straight into railway carriages for quick freight evacuation. This automated fertiliser bagging facility can load 20 rakes each day. The port also has a lot of storage capacity in the formof open and covered warehouses. The cargo volume in Mundra Port was 115 MMT from December 1 to December 21, with Foreign Transhipment accounting for 30% of the total.

The Seybold Report
ISSN 1533-9211

3. LITERATURE SURVEY

Evaluation of port performance is important for policy suggestions, port destination selection, and researchavenues for various stakeholders. Port performance measurement, which began with ideas for indicators and has expanded to include efficiency and productivity measurements, is now being graded based on manyfactors. Several researchers have used the DEA technique to evaluate port performances. The use of the DEA approach in the port sector is not a new concept. In many places around the world, several forms of the DEA technique have been applied to study port production. Unlike the port performance indicators created by UNCTAD (1976), the advantage of DEA is that other inputs and outputs may be added to the model, allowing it to provide an overall evaluation of port performance (Wang et al., 2003).This section reviews the available literature on port efficiency measurement based on DEA in the Indian context to identify the research gap/s.

Chudasama and Pandya's (2008) study is the first one to measure the efficiency of Indian ports by using Data Envelopment Analysis (DEA). Their main objective was to bring out the actual working and performance of 12 major ports of India for the year 2005-06. They found that "the DEA-BCC model yieldshigher efficiency estimates than the DEA-CCR model, with average values of 0.98 and 0.86, respectively.Out of the 12 ports, seven were identified as efficient, and five were relatively inefficient when the DEA- CCR model was applied. When the DEA-BCC model was used, all the ports except one turned out to be efficient in the analysis." Empirical results also showed that a large production scale is more likely to be associated with high-efficiency scores. For instance, the efficiency score and port output correlation were 0.84 for the DEA-CCR model.

Similarly, the study by Kamble et al. (2010) used data envelopment analysis on chosen input and output variables to assess the efficiency of the major Indian seaports. Storage facilities, the number of berths, andthe quantity of cargo handling appliances were the input variables. The two output variables included wereaverage total turnaround time and average output per ship berth day. As per this study, "only six of the twelve ports were verified to be operating efficiently." In contrast, the study by Haralambideset al. (2011)assessed the efficiency of 26 dry ports in India's Jawaharlal Nehru Port Trust region while also considering the critical problem of container security. Their findings showed that "the public-sector dry port ownership arrangements and competition rules significantly impacted the development of container security methodsand, as a result, dry port operational efficiency."

The study by Munisamy and Singh (2011), on the other hand, examined the technical and scale efficiencyof major container ports in Asia, including India. This study used the non-parametric DEA technique. According to the findings, Asian container ports had an average technical efficiency of 48.4 percent, and the technical inefficiency was due to pure technical inefficiency rather than scale inefficiency. As per the results of the comparison across nations, Bangladesh, the Philippines, China, Cambodia, India, and Singapore have the most efficient ports in Asia.

Sekar and Deo (2012) used DEA – Additive models to look at the relative efficiency of India's major portsfrom 1993 to 2011. They choose the inputs and outputs for the study by evaluating variables such as the number of berths, berth length, number of equipment, number of staff, container throughput, and total cargodirectly associated with port efficiency. According to the findings, "both larger ports (JNPT, Mormugao) and smaller ports (Ennore, Tuticorin) were efficient. As a result, it was demonstrated that there is no substantial difference in port size and efficiency." Similarly, in another study, Sekaret al. (2014) used dataenvelopment analysis to look at the operational efficiency of a few major Indian ports from 1993 to 2011. They concluded that the port size had no bearing on port efficiency as both larger ports - Mormugao and the Jawaharlal Nehru Port Trust, and smaller ports, such as Ennore and Tuticorin, were found to have efficient port operations throughout.

Dasgupta and Sinha (2016) attempted to identify the effect of liberalization on the efficiencies of containerterminals of major ports of India. In their study, the efficiency of privately managed terminals under majorports was compared with public container terminals with the help of the output-oriented DEA using DEAP (Data Envelopment Analysis (Computer) Programme) software. The study results showed that "though theefficiency of container terminals is affected by privatization to a great extent, they depend on other factorstoo."

Iyer and Nanyam's (2021) study looked at the technical efficiency of 26 container terminals in India during2015–2018 using a data envelopment analysis approach. The study discovered that "container terminals onIndia's west coast were more efficient than those on the east coast. The efficiency of container terminals operating under major ports is dropping compared to that of minor ports." Besides, it was shown that the size of the terminal, which offers economies of scale, is the most crucial element impacting its efficiency.Furthermore, it was found that there was no consistent increase in productivity across all container terminals due to private participation.

In contrast, Mustafa et al. (2021) attempted to compare the technical efficiency of less-explored South Asian and Middle Eastern ports to East Asian ports to find strategies to improve their efficiency and management. For 2018, cross-sectional data were collected for 15 container ports in the South & Middle Eastern and East Asian regions, and input and output variables were created. The DEA-CCR and DEA- BCC models were used to examine the data. Only one port in South Asia, JNPT in India (from JNPT, Hazira, Pipavav, and Mundra), was determined to be efficient on the CCR model. Still, the number of efficient ports on the BCC model increased by 47 percent.

Adler et al. (2021) devised a set of contextual factors, including an absolute measure of specialisation anda berth-level measure of ownership structure for understanding the efficiency drivers of ports in India. Thisformulation was applied to major Indian seaports for21 years, from 1995 to 2015. The findings indicated that "average seaport efficiency has gradually grown over time. According to the second stage, fixed effectsregressions, specialization, and external stakeholder(private) participation significantly influenced seaportperformance. Surprisingly, competition between major and minor seaports was found to impact performance negatively.

Although several studies on measuring port efficiency have been conducted in India, the major shortcomingof these studies is that they have not focused on analysing the efficiency of the ports operating under different administrative control, such as the public sector port and private port. This is the primary motivating factor for the conduction of this study.

4. SOURCES OF DATA AND METHODOLOGY

Data source

The data on various parameters of the performance of the ports were systematically collected and collatedfrom the respective port managements, viz, the Deendayal Port Trust and Adani Ports & SEZ Ltd, Mundra.

Methodology

Every firm is concerned about technical efficiency. Technical efficiency refers to how a firm reduces input consumption in the production process to achieve a certain output level or maximises output without changing any input units. Many methodologies have been developed to quantify technical efficiency in various sectors. The non-parametric DEA methodology is one of the most often utilised measuring methodologies. It is a type of linear programming used to evaluate the effectiveness of a decision-making unit (DMU). Two popular models are extensively used. One DEA-CCR assumes constant returns to scale,while the other DEA-BCC assumes variable returns to scale, with the DEA-CCR with a constant return toscale receiving the most significant support.

This investigation uses an input-oriented approach to see the possibility of reduction in input and the consequent effect of change in output. Let a set of DMU_j (j=1,…., n) be in the measurement system. Let $(x_{1j},\ldots,x_{mj})$ be the input vector of DMU_j and input weight vector $(v_1,\ldots, v_m)$,. Let $(y_{1j},\ldots,y_{qj})$ be the output vector of DMU_j and output weight vector $(u_1,\ldots, u_q)$. Assume that each DMU_j consumes x_{ij} amount of input i to produce y_{rj} amount of output r and that the input and output of DMU_k(k=1,….,n) being investigated are, respectively, $(x_{1k},\ldots,x_{mk})$ and $(y_{1k},\ldots,y_{qk})$, where $x_{ik}\geq 0$ and $y_{rk} \geq 0$. Let $\mu_r=tu_r$ and $v_i= tv_i$, where $t = (\sum_{i=1}^{m} v_i x_{ik})^{-1}$

(i) The input-oriented CCR-DEA model has the following form

$$max = \frac{\sum_{r=1}^{q} u_r y_{rk}}{\sum_{i=1}^{q} v_i x_{ik}}$$

$$\text{Subject to} \begin{cases} \dfrac{\sum_{r=1}^{q} u_r y_{rj}}{\sum_{i=1}^{q} v_i x_{ij}} \leq 1 \; (j=1,\ldots,n) \\ u_r \geq 0 \; (r = 1,\ldots, q) \; v_i \geq 0 \; (i = 1,\ldots, m), \end{cases}$$

(ii) The input-oriented BCC-DEA model has the following form

$$max \sum_{r=1}^{q} \mu_i y_{rk} + \mu_0$$

Subject to
$$\begin{cases} \sum_{r=1}^{q} \mu_i y_{rj} - \sum_{r=1}^{m} v_i x_{ij} + \mu_0 \leq 0 \quad (j = 1, \dots, n), \\ \sum_{i=1}^{m} v_i x_{ik} = 1, \\ u_r \geq 0 \ (r = 1, \dots, q) \ v_i \geq 0 \ (i = 1, \dots, m), \ \mu_0 \in R, \end{cases}$$

The current study assesses the efficiency of two major ports in Gujarat using the above models. It comparesprivate and public-sector port performance from 2017 through 2022. On the input side, total berth, numberof cranes, labour engaged, and berth length are being investigated; container throughput and total traffic are being considered on the output side. The investigation was divided into three parts. The first section establishes the framework for the Mundra port analysis. The DEA model creates an efficient frontier froma data sample of the best-performing decision-making units. The second part examines Kandla Port, and thethird part constructs DEA from the Mundra panel and the Kandla Port sample's efficient frontier.

5. RESULTS AND DISCUSSION

Mundra Port

The constant return to scale-input-oriented data envelopment analysis results is shown in Table 1. Where, for the year 2017-18, the optimal result of efficiency score is denoted by (theta), reference weights are denoted by (lambda A, lambda B, lambdaC, lambdaD, lambdaE), and slack is denoted by (i.number of berths, i.number of cranes, i.number of labour, i.berth length, throughput in TEC The Mudtra port performed well this year, as evidenced by its efficiency score of one. Similarly, for the year 2018-2019, theta score, reference weights, and slack imply 0.923668, (0.111404, 0,0,0,0.812265), and (0,0,0,0,1156967, 0.0434), respectively. This year, we estimate that the port's efficiency was 92.36 percent.In this reference period, the port could have boosted throughput by 1156967 and improved traffic by 0.0434to reach the efficient border. Put another way, and the port should have boosted container traffic by 1.31 percent and increased container volume by 25% to be more efficient.

Whereas theta score, reference weights and slack for the reference period 2019-2020 suggest 0.831111, (0,0,0,0,0.831111), and (0,0,220.244,0, 544612, 0.0000792) respectively. This year, the port's

Source: Author's calculation

Note: R=Ranks, Theta=Efficiency Score, Lamda=reference weights, TB=Total Berth, C= No of Cranes, L= Labor, BL= Berth Length, CTP= Container Throughput, TT= Total traffic.

Table 1: Constant return to scale- input-oriented DEA efficiency Results													
Year	Rank	theta	λA	λB	λC	λD	λE	TB	C	Input and output slacks			
										L	BL	CTP	TT
2017-18	1	1	1	0	0	0	0	0	0	0	0	0	0
2018-19	4	0.92	0-111	0	0	0	0.81	0	0	0	0	1156967	0.0434
2019-20	5	0.83	0	0	0	0	0.83	0	0	220.2	0	544612	0-0792
2020-21	3	0.96	0-23	0	0	0	0.72	0	0	0	0	0	198.065
2021-22	1	1	0	0	0	0	1	0	0	0	0	0	0

performance was up to 83.11% efficient. And to move to the efficient frontier that is 1, the port could havereduced the labor by 220.244 units, increased the throughput by 544612, and improved the traffic by 0.0000792 in this reference period. In other words, to have been efficient, the port should have increased the containers by 11.29% and improved the traffic by 2.64%.

Subsequently the theta score, reference weights and slack for the reference period 2020-2021 derive 0.960092, (0.231593,0,0,0,0.728499), and (0,0,0,0,0,198.065) respectively. This year, we obtained that theport's performance was efficient up to 96%. And it could have been efficient fully if the port could have improved the traffic alone by 198.065 in this reference period. In other words, to have been efficient, the port should have improved the traffic by 3.50%.

Table 2: VRS input-oriented DEA Efficiency Results				
Year	CRS-TE	VRS-TE	SCALE	RTS
2017-18	1.000000	1.000000	1.000000	-
2018-19	0.923668	1.000000	0.923668	IRS
2019-20	0.831111	1.000000	0.831111	IRS
2020-21	0.960092	1.000000	0.960092	IRS
2021-22	1.000000	1.000000	1.000000	-

calculation Source: Author's

For the reference period 2021-2022, the data has been extrapolated from October 2021 to March 2022. Accordingly, the result of theta, reference weights, and slack have been worked out. The obtained result values denote the fully efficient performance of the Mudhra port in this particular period. Hence port efficiency analysis of referred years reveals that performance has been good in 2017-18 & 2021-22. And these years can be a benchmark for subsequent years to come.

In the table-2, variable return to scale is specified. This gives additional information about the efficiency of the port in the referred years. For instance, in the year 2017-18 and 2021-22, the port enjoys constant return to scale, and in the rest of the year, it is faced with increasing return to scale.

Kandla Port

The table-3 presents the review of five years' performance analyses of Kandla port. In 2020-21 the port achieved a strong performance index for the rest of the years. The result record of data envelopment revealsfully efficient scores of 1, and all slacks, both input, and output, are zero. Since dual conditions are satisfied,i.e., efficiency being 1 and all slacks being zero, the firm has functioned efficiently in terms of radial, technical and Pareto-efficient.

Kandla port performed efficiently in 2020-21 given the input and output combinations whose theta is one and slacks are zero. Assessing other years' performance relative to the technically efficient frontier in 2020-21 reveals that in 2017-18, 2018-19, 2019-20, and 2021-22, the deviation from the efficient frontier has been 0.28, 0.53, 0.94, and 0.90 respectively. However, it can be noticed that the two years, 2019-20 and 2021-22, theta are close to the efficient frontier.

The optimal result of efficiency score theta, reference weight lambda and slack of input & output was obtained for the reference period of 2017-18. Theta, reference weights, and slacks obtained for the year 2017-18 confirm 0.28, (0,0,0.22,0), and (0.10,0.422,0,28.80,0,76180.2) respectively. Thus, if the port hadmade an effort to reduce the total number of berths by 0.105693 and the number of cranes by 0.422772, berth length by 28.8013 units, or maximise the total quantity of traffic by 76180.0, the port's performancein the year 17-18 may have been improved. This could have enhanced the port's efficiency, allowing it to achieve theta equal to one. However, because there is no slack in labour, it has been used to its full potentialover the referred period. Similarly, the port's economic activity in 2018-19 yielded an efficiency score of 0.54, which is significantly lower than the efficient frontier score of one. The recorded reference weights and input-output slacks support the following (0,0,0,0.4745,0), (0.12,0.4802,0,32.71,200.343 ,0). The port'sperformance might have been improved if the total number of berths was lowered by 0.12, cranes were reduced by 0.4802, berth length was reduced by 32.71 units, or the throughput was increased

Table 3: Constant return to scale- input-oriented DEA efficiency Results of Kandla Port

Year	Theta	i-TB	i-C	i-L	i-BL	o-CTP	o-TT
2017-18	0.282351	0.105693	0.422772	0	28.8013	0	7680.2
2018-19	0.534569	0.120064	0.480255	0	32.7173	200.343	0
2019-20	0.942192	0.151154	0.604615	0	41.1894	0	215075
2020-21	1	0	0	0	0	0	0
2021-22	0.906075	0	0	15.4033	0	29810.3	0

Source: Author's calculation

Note: Theta=Efficiency Score, TB=Total Berth, C= No of Cranes, L= Labor, BL= Berth Length, CTP= Container Throughput, TT= Total traffic.

to 200.343 units. Such input-output management may have resulted in a port's scale and technical efficiencyscore in this period.

The theta value for the evaluation period 2019-20 is 0.9421, which is closer to the efficient frontier. On reference weights and input-output slacks, the results are (0,0,0,0.8666,0),

The Seybold REPORT
ISSN 1533-9211

(0.15,0.6046,0,41.18,0,215075), respectively. Although the port operated efficiently closer to the frontier, it might have been on the frontier if it loweredinputs such as total berths by 0.15, cranes by 0.6046, and berth length by 41.18 units or raised total trafficby 215075. The Kandla port's efficiency scores for 2020-21 may be seen using theta, reference weights, and input-output slacks. Theta value of 0.906075 is slightly off the efficient frontier, implying a strong response to full efficiency. The input-output slacks can be stated in the following way: (0, 0,15.40,0,29810.3,0). According to the input slacks, the port could have achieved the scale and technical efficiency if it had saved 15.40 units of labour or boosted throughput by 29810.3.

Table-4: Variable Return to Scale Frontier for Kandla Port				
Year	**CRS-TE**	**VRS-TE**	**SCALE**	**RTS**
2017-18	0.282351	1.000000	0.282351	IRS
2018-19	0.534569	1.000000	0.534569	IRS
2019-20	0.942192	1.000000	0.942192	IRS
2020-21	1.000000	1.000000	1.000000	-
2021-22	0.906075	1.000000	0.906075	IRS

Source: Author's calculation

The VRS DEA values differ from the CRS DEA estimated efficiency score values in table-4. Although theVRS DEA efficiency ratings demonstrate total efficiency across the reference period more than the CRS DEA, optimal benchmarking efficiency evaluations are based on the CRS frontier (Coelli,2008). If CRS istaken into account, Kandla port has fared well only in 2020-21.

Table-5: Constant Return to Scale Input Oriented DEA Efficiency Results of Mundra and Kandla Port

	Year	R	Theta	λ A	λ B	λ C	λ D	λ E	λ F	λ G	λ H	λI	λ J	i-TB	i-C	i-L	i-BL	o-CTP	0-TT
	2017-18	8	0.576	0	0	0	0	0	0	0	0	7.99	0	1.3	0	5671.1	2415.1	0.11	0
M-port	2018-19	7	0.636	0	0	0	0	0	0	0	0	8.84	0	1.4	0	12436.3	2668.3	0	0
	2019-20	6	0.675	0	0	0	0	0	0	0	0	9.37	0	1.5	0	14267.1	2830.1	0	0
	2020-21	5	0.792	0	0	0	0	0	0	0	0	11	0	1.8	0	14421.6	3320.2	0	0
	2021-22	4	0.904	0	0	0	0	0	0	0	0	12.5	0	2	0	18865.5	3789.8	0.03	0
	2017-18	10	0.282	0	0	0	0	0	0	0	0	0.22	0	0.1	0.4	0	28.801	0	7680
K-Port	2018-19	9	0.534	0	0	0	0	0	0	0	0	0.47	0	0.1	0.4	0	32.717	200.3	0
	2019-20	2	0.942	0	0	0	0	0	0	0	0	0.86	0	0.2	0.6	0	41.189	0	215075
	2020-21	**1**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
	2021-22	3	0.906	0	0	0	0	0	0	0	0	0.91	0	0	0	15.4	0	29810	0

Source: Author's calculation

Note: M=Mundra Port, K=Kandla Port, R=Ranks, Theta=Efficiency Score, Lamda=reference weights, i=input, o=output, TB=Total Berth, C= No of Cranes, L= Labor, BL= Berth Length, CTP= Container Throughput, TT= Total traffic.

A combined efficiency measure gives a different picture compared to individual efficiency tests. The efficiency test for both Mundra and Kandla ports is shown in Table -5. When the two ports are combined,Kandla port has an efficient benchmarking frontier in 2020-21, with a score

The Seybold REPORT

ISSN 1533-9211

of one. Using this as a benchmark for the rest of the year's performance reveals the various levels of efficiency. The completed analysis shows no efficiency for Mundra port in any year, but efficiency for Kandla port in 2020-21, whereas Mundra port had shown efficiency for two consecutive periods in separate analyses (2017-18 & 2021-22).

Table-6: Variable Return to Scale Frontier for Mundra and Kandla Port

DMU	Year	Ranks	CRS-TE	VRS-TE	SCALE	RTS
	2017-18	8	0.576368	1	0.576368	DRS
	2018-19	7	0.6368	0.71	0.6368	DRS
Mundra port	2019-20	6	0.675415	0.74	0.675415	DRS
	2020-21	5	0.792398	0.95	0.792398	DRS
	2021-22	4	0.9044	1	0.9044	DRS
	2017-18	10	0.2823	1	0.2823	IRS
	2018-19	9	0.5345	1	0.5345	IRS
Kandla Port	2019-20	2	0.9421	1	0.9421	IRS
	2020-21	**1**	**1**	1	**1**	CRS
	2021-22	3	0.906075	1	0.906075	IRS

Source: Author's calculation

A combined examination of variable returns to scale in table-6, on the other hand, shows Mundra Port to be in the opposite situation. For example, in 2017-18 and 2021-22, the Mundra-port experienced a constantreturn to scale, while the rest of the year saw an increasing return to scale. However, the VRS frontier of Mundra port demonstrates a declining return to scale over time in a combined analysis. Except for 2020- 21, Kandla port operates on the principle of rising returns to scale.

6. CONCLUSION

In this paper, the Mundra and Kandla ports were evaluated for efficiency. The evaluation's findings suggestthat the efficiency of these private and public-owned ports differs. Using DEA in the capacity of individualefficiency study, the Mundra port has an average efficiency of 0.9275 percent for the reference period. Theefficiency representation of the Mundra port is consistent when compared to its counterpart. As a result, Mundra Port's performance is exceptional on its own. This was proven by comparing the average efficiencyscore of Mundra and Kandla ports over the same period. Mundra's average efficiency score is 0.92 percent,which is higher than the 0.73 percent of its counterpart. This evidence emphasizes a close examination of the Kandla port and learning about the many input-output combinations.

Following that, compelling inference can be taken. On the other side, when DEA is worked on the cross-section panel, DEA sets an efficient frontier from Kandla Port in 2020-21. In this case, the yearly efficiency and average efficiency of Mundra Port reboundeddownward, and Kandla port remained the same. Mundra port's average efficiency dropped from 0.92 percent to 0.71 percent. Mundra Port is ten times larger than Kandla Port in container handling capability. Mundra port's efficiency rankings in this category are excellent. Furthermore, both ports have a lot of infrastructure asymmetries, despite their enormous potential. The unique characteristic of Mundra port, incontrast to Kandla port, is that it is located within a special economic zone.

Mundra port's average efficiency dropped from 0.92 percent to 0.71 percent. Mundra Port is ten times larger than Kandla Port in container handling capability. Mundra port's efficiency rankings in this category are excellent. Furthermore, both ports have a lot of infrastructure asymmetries, despite their enormous potential. As a privately operated port in a special economic zone, Mundra port has excellent infrastructure and draws more ships. As a government-owned port, Kandla port could consider leveraging its traditional strengths in handling bulk cargo through modernization efforts by utilising the policy focus of the Sagarmala Project of the Government of India and building capacity more quickly. Other policy clearances and tendering-related difficulties must be addressed to improve Kandla port's performance.

In conclusion, our findings suggest that incorporating external stakeholders improves technical efficiency in ownership structure. The landlord seaport concept reduces public sector budget demands and improves port performance. As a result, the environment should be more conducive to public-private partnerships, with terminal operators being provided with an environment that allows concession contracts to last for theproject's duration. On the other hand, the landlord port model can only be successfully implemented if portauthorities have good corporate governance and capacity.

Based on the foregoing, the following recommendations are made: (a) promote private sector participation through a well-developed institutionalframework, including continued adoption of the landlord port model; (b) improve governance of port authority boards; and (c) promote competition between and within ports, in part through transparent and competitive concession bidding. Needless to say, good corporate governance and transparent business practices are a sine-qua-non, not only for publicly owned port entities but also for privately owned port entities to perform efficiently and effectively and deliver optimal outcomes.

The future study could involve a thorough examination of each port's enabling and inhibiting aspects affecting its operational and financial efficiencies. Models could be built to understand the quantitative impact of these factors on container port efficiency. This research can be developed to estimate the profitability and sustainability of ports once the proper input and output variable data are readily available.

There are certain limitations to this study. Instead of the second stage DEA, one could use the distance function approach, Bayesian techniques, and Monte Carlo techniques. In addition, the impact of qualitative elements such as unstable situations, government reforms, hinterland connectivity, management, and so onmight be examined. Future research should evaluate the Indian port's cost efficiency, as this study estimatestechnical efficiency.

References

1) Adler, N., Hirte, G., Kumar, S., &Niemeier, Hans‐Martin. (2021). The impact of specialization, ownership, competition, and regulation on efficiency: A case study of Indian seaports, Maritime Economics & Logistics, Retrieved from https://doi.org/10.1057/s41278-021-00200-y

2) Chudasama. K. M.,& Pandya, K. (2008). Measuring Efficiency of Indian Ports: An Application of Data Envelopment Analysis, The IUP Journal of Infrastructure, June, 22-34.

3) Coelli, T.J. (2008) A Guide to DEAP Version 2.1: A Data Envelopment Analysis (Computer) Program. Working Paper of the University of New England/Center for Efficiency and Productivity Analysis.

4) Dasgupta, M. K., & Sinha, D. (2016). Impact of privatization of ports on relative efficiency of major portsof India, Foreign Trade Review, 51(3), 225–247.

5) Haralambides, H., Gujar, G., & M. Jain, M. (2011). Dry Port Efficiency and Container Security, paper presented at the International Association of Maritime Economists (IAME)At: Santiago, Chile, October, Retrieved from https://www.researchgate.net/publication/299430025Dry_Port_Efficiency_and Container Security

6) Iyer, K.C, &Nanyam, V.P.S. (2021). Technical efficiency analysis of container terminals in India, The Asian Journal of Shipping and Logistics, 37 (1), 61-72.

7) Kamble, S.S., Raoot,A. D., &Khanapuri, V. B. (2010). Improving port efficiency: A comparative study of selected ports in India. International Journal of Shipping and Transport Logistics, 2 (4), 444-470

8) Monteiro, J. G. R. (2018). Measuring productivity and efficiency of seaports in Indiausing DEA technique. The Central European Review of Economics and Management,2(3). 155-174.

9) Munisamy, S.,& Singh, G. (2011). Benchmarking the efficiency of asiancontainerports. African Journal of Business Management, 5(4), 1397–1407.

10) Mustafa, F.S., Khan, R.U., & Mustafa, T. (2021). Technical efficiency comparison of container ports in Asian and Middle East region using DEA, Asian Journal of Shipping and Logistics, 37(1), 12-19.

11) Sekar, R. T., & Deo, M. (2012). The Size Effect of Indian Major Ports on its Efficiency Using Dea-Additive Models, International Journal of Advances in Management and Economics, 1(5), 12-18

12) Sekar, R.T., P.S. Ashraf., & Deo. P M. (2014). Measurement of efficiency of major ports in India – A data envelopment analysis approach. International Journal of Environmental Sciences, 4 (5), 926–936.

13) Wang, T., Song, D., & Cullinane, K. (2003) Container Port Production Efficiency: A Comparative Studyof DEA and FDH Approaches, Journal of the Eastern Asia Society for Transportation Studies, 5, 698-713.

14) UNCTAD (1976) Port Performance Indicators, TD/B/ C.4/131/Supp.1/Rev.1. United Nations Conference on Trade and Development, New York.