Journal of Sustainable Development of Transport and Logistics
journal home page: https://jsdtl.sciview.net

Nze, O. N., & Ejem, A. E. (2020). Sensitivity analysis of performance of Nigerian ports using data envelopment analysis. *Journal of Sustainable Development of Transport and Logistics, 5*(1), 37-47. doi:10.14254/jsdtl.2020.5-1.4.

Scientific Platform

ISSN 2520-2979

Sensitivity analysis of performance of Nigerian ports using data envelopment analysis

Obiageli N. Nze *, Ejem Agwu Ejem **

* *National Centre for Technology Management,*
South-East Zone, Enugu, Nigeria
** *Department of Transport Management Technology, Federal University of Technology,*
Owerri, Imo State, Nigeria
ejem.ejem@futo.edu.ng

OPEN ACCESS

Article history:

Received: December 31, 2019
1st Revision: January 04, 2020
Accepted: April 07, 2020

DOI:
10.14254/jsdtl.2020.5-1.4

Abstract: With cognizance to some differences among the ports and complexities in productivity measurement, the research tries to identify and evaluate productive issues in terms of technical efficiencies (managerial efficiency) and scale efficiencies (managerial and allocative efficiency) experienced at individual Nigeria ports. It equally provided a technical benchmark for assessing the overall efficiencies of the respective ports in Nigeria during the pre-concessioned and post-concessioned era. The level of inputs required for each DMU to be efficient is given i.e. for DMU 2014 to be efficient input-wise, the number of berth may be reduced by two units as a result of idleness of this two (2) berths, the average turnaround time may be reduced by 3 hours and the berth occupancy may be reduced by 3%. Since a fixed asset such as berth cannot be reduced therefore technically and complimentarily the turnaround time and berth occupancy rate need to be decreased more than 5hours and 3% respectively by allocating the queue ship at the over-utilized berth to the idle berths which in turn will mitigate underutilization of this berths been required to be reduced or alternatively the port should embrace more cargo handling technology to enhance fast loading and discharging of cargoes thus attracting more vessels to the Port.

Keywords: Nigerian ports, sensitivity analysis, data envelopment analysis, sustainability.

1. Introduction

In an increasingly competitive world economy, the importance of productivity enhancement has become even more fundamental. Countries with high productivity tend to become dominant in global markets, while low productivity countries become increasingly marginalized (Oshiomhole, 2006).

Corresponding author: *Ejem Agwu Ejem*
E-mail: ejem.ejem@futo.edu.ng

In a standard setting, it is important and feasible for firm/industry either private or public to assess their productivity for some cogent reasons which may include.

i. Economic reasons
ii. Technical reasons

In order to ventilate on these mentioned points. It would be viable to deploy them in a well-structured system such as port system.

Economic Reasons: A port as a significant system and a complex service-oriented business should always strive to avoid unnecessary waste or expenditure of input resources such as time, labour and other assets because of the complexity in the system. In other words, an efficient system must fulfil the three economic reasons which are how much of each product or service is to be produced or rendered? How much of each input resource is to be employed in the production of each product/service? Finally how to distribute the product or service among users? This reasons help to determine the relationship between total costs of inputs and port production which include whether cost of running a port sub-system or the overall system is/are adequate and whether additional input resource(s) to the production process would be feasible. Economically, these questions can be expressed in another angle such as;

a. Is the port making a profit, loss or a break-even when compared to the revenue received?
b. Secondly can these costs be used for evaluating the balance of the port's level of input resources to profits and losses? and
c. Thirdly can these costs be analyzed for decision making purposes by the port for example to investigate whether the port exhibits economies of scale and economies of scope?

These questions can only be imminently answered when the input-output analysis is done at the end of the production period.

Economical reason why productivity should be assessed is to check the cost-benefit analysis of using an input resource over another that is whether the port output is produced at the least cost at the given resource prices to be paid by the port operator. A port's economic cost function represents the relationship between the ports' minimize costs to be incurred in handling a given level of output (Talley, 2009).

$$Min\ (Port\ Costs) = g(Port\ Output)$$

In order for a port to be cost efficient it must be technically efficient.

Technical Reason: This is another reason why port productivity should be measured at a definite period. In order to know whether the 4Ps of production that is product, people, process and price are well structured it is necessary to determine the current status of productivity. Evolution in maritime and shipping industry have led to severe technological trends which in turn as resulted to economies of scale for some operators/firm which one way or the other have largely utilised the technologies with respect to the technicality of port/terminal operations as port/terminals that do not upgrade according to the trends end up lagging behind the international standards. Therefore reappraisal of production is a very crucial measure to ascertain through technical aspects of the process how much the port is getting along with the technological trends and how much they utilized the technologies. This can probably be achieved by some computation with the aids of the required input-output models or analytical tools that deal with optimization of production input resources to obtain the best possible units of output(s) for instance, Data Envelopment Analysis.

In this competitive and globalizing market it is advisable and ideal for port service provider to check their productivity and production line especially at a fiscal year in order to check mate hiccup(s) in the production process if there is any and also to meet up with the trends.

2. Literature review

Data Envelopment Analysis (DEA) does not impose any particular functional form on the data as it creates flexible piecewise linear function unlike regression. DEA is a good tool to evaluate more performance (Lin, Wu, Chu & Liu, 2005). They found out the distinctions between DEA and linear regression analysis through the application of these models for the performance efficiency evaluation of the Taiwan's Shipping Industry. In their research, considering 14 shipping companies as Decision

Making Units (DMUs) and using the two (2) input variables which include assets; stockholders' equity and also two (2) output variables which include operating revenue and net income. From their analysis he observed U-Ming, YML, WAN HAI and Shanloong as the most efficient with DEA efficiency score 1.0000 while U-Ming was the first efficient shipping company. When considering linear regression analysis of the inputs to the output operating revenue and Taiwan Line was first efficient shipping company when considering linear regression analysis of the inputs to the output net income. The researchers identified the drawbacks of regression as the correlation and relationship of input variables to only one output variable at a time. The differences in the analysis of the DEA and linear regression analysis enabled the researcher to conclude that DEA analysis adopts best performance as the criteria for efficiency computation while regression uses the average performance as the yardstick for computations.

Table 1: Sensitivity Analysis of Taiwan Line (Shipping Company in Taiwan)

Variable name	Estimated weight	Value measured	Value if efficient	Slack
Operating revenue	0.5598987	2,357,181	2,357,181	0
Net Income	0.178606	771,641	771,641	0
Assets	0.00000001	5,991,346	5,991,346	0
Equity	0.4242356	4,525,048	4,214,974	310,074

Source: (Lin, Wu, Chu & Liu, 2005)

From the above analysis, it was observed that by satisfying all the constraints, the estimated weights of the input and output variables are the best possible combination of weight that can produce the relative efficiency of this DMU (0.8042).

Data Envelopment Analysis (DEA) provides numerous benefits over Cost-Benefit Analysis (CBA) and Multi-Criteria Analysis (MCA) thus considering this attributes, Caulfield, Bailey, and Mullarkey (2009) recommended DEA as a powerful decision making tool for similar transport investment as they used this analytical tool as a public transport project appraisal tool. The aim of their research was to evaluate and select the best possible mode(s) to be used between Dublin city centre - airport route by employing one (1) input variable Cost which encompass Construction costs; operation costs; maintenance costs and three (3) output variables: number of car trips removed; patronage; travel time saving, all attributed to six (6) possible transportation modes which represent DMUs which include 16, 41, Metro North, BRT Airport, Luas Airport and DART Spur. They explained the reason for selecting the number of input and output variables against the six (6) DMUs as a fact made by Cooper, Seiford and Tone (2000) that if the number of DMUs is less than the combined number of inputs and outputs then a large portion of the DMUs will be identified as efficient and bias will be removed. Subsequently, they deduced from CCR-output oriented analysis that BRT Airport and DART Spur are the most efficient transportation solution for the airport route followed by Lucas with 83% efficiency score and BBC-output oriented analysis (scale efficiency) showed that BRT Airport, DART Spur, Route 16 and Metro North are routes that possess high operating performance relative to their locations. It was conversed that the overall global inefficiency (50%) experienced by route 16 was as a result of inefficient operation rather than scale problems scale problems which he suggested and also concluded that Metro North and Lucas Airport who has 100% BCC score and relatively low scale efficiency of 66% and 83% respectively are suffering from scale size rather than inefficient operation. They recommended that operational efficiencies of these subsequent routes should be improved to meet up with the scale of frontiers (BRT Airport and DART Spur) by reducing costs and infrastructure size.

Data Envelopment Analysis and Free Disposal Hull (FOH) allow the measurement of the relative distance that an individual decision making unit lies away from its estimated frontier (Kaisar, Pathomsiri, Haghani & Kourkounakis, 2006). They carried a research on developing measures of U.S ports productivity and performance using two powerful analytical tools named Data Envelopment Analysis (DEA) and Free Disposal Hull (FOH) to analyze and evaluate input variable number of berth, length of berth, total terminal area, storage capacity, number and size of ship shore crane; front and handlers; yard tractors; yard chassis at the ports and output variable TEU of 29 U.S seaports through which they observed that in 1996 eleven (11) out of twenty-nine (29) ports had perfect efficiency score of 1 according to DEA-CCR input-oriented analysis, sixteen (16) ports out of twenty-eight (28) were efficient according to DEA-BCC input-oriented analysis and twenty-four (24) out of twenty-nine

(28) ports were efficient according FDH analysis. In 2001, thirteen (13) ports had out of twenty-nine (29) perfect efficiency score of 1 according to DEA-CCR input-oriented analysis, nineteen (19) and twenty-four (24) ports out of twenty-nine ports were efficient according to DEA-BCC input-oriented analysis and FDH analysis respectively. They further test the authentication of these diversified analysis of these analytical tools by employing Spearman's rank order correlation coefficient thus obtained the correlation values between the efficiency derived by DEA-CCR, and DEA-BCC, DEA-CCR and FDH, and DEABCC and FDH methods to be 0.99273, 0.98118, and 0.99730 respectively. The positive and high Spearman's rank order correlation coefficients indicate that the rank of each DMU derived by the three methodologies is similar. Also, the small absolute value of the spearman's rank suggests that the efficiency of ports is not a significant influence by its size.

The application of Data Envelopment Analysis can be seen from the research Van-Dyck and Ismael (2015) carried on the assessment of port efficiency in West Africa using secondary data of input variables total quay length; terminal area; number of quayside cranes; number of yard gantry cranes; number of reach stackers and output variables container throughput for the period 2006-2012 which he deduced that Lagos port has the highest throughput of 1,623,141 ton in 2012 (post-concession era) but suffers from throughput fluctuation over time as other ports except Cotonu Port who experienced stability of throughput during the studied years though Cotonu port has the least average efficiency score of 46% placing them as the last (6^{th}) ports on his efficiency ranking table reflecting the attribute of underutilization of infrastructure at the port which make the writer referred them to as under-achiever, the port of Tema has 91% average efficiency score which placed them first on the efficiency ranking table, the port of Abidjan is the second on the table with efficiency score of 90% followed by port of Lome with efficiency score of 88% then Lagos Apapa Complex as fourth position on the table with 76% irrespective of her unique attributes as a port that has largest size among these West African ports studied and located in a country that has largest economy in Africa which reflects the attributes of low efficiency in the port thus it shows the strength of DEA as an unbiased analytical tools. The port of Dakar precedes Lagos port complex with average efficiency score of 62% even though she exhibit maximum level of efficiency of 72% between 2006 and 2009 but declined in the preceding years to 68%, 56% and 53% and lastly port of Cotonu. He related causes of inefficiencies of ports to smaller customer base and lack of adequate output resulting from the level inputs were being utilized in port operations which he that recommended shipping lines in West Africa should ensure that a potential hub ports exhibits high port efficiency and performance.

The insight of the application of DEA can also be seen in the research carried by Hajizadeh, Nasser, Amer, Homayoun, Mostafa (2016) on relative efficiency analysis of container ports in Middle East using DEA-AP to analyze the input variables berth, berth length, terminal area and quay/yard gantry and output variable throughput for 2011-2013 on twelve (12) ports located in five (5) countries like Islamic Republic of Iran, United Arab Emirates, Saudi Arabia, Oman and Egypt with DEA-BCC output oriented which considered ports of Bushehr, Khorfakkan which has most referenced shadow price, Jebel Ali and Alexandria most efficient ports with efficiency score 1 and port of Oman as the most inefficient. He concluded that managers or operators of these ports experienced increase in output which in turn increased efficiency as a result of expansion of the input capacity. He concluded that three Iranian ports among the ports studied have low relative efficiencies according to the implementation of the BCC model (pure technical efficiency) depicting port inefficient in management of operations. Thus he recommended that managers of inefficient ports should focus on improving management approaches and handling of the operations. The limitation to the application of the model may arise as a result of lack of data unavailability at individual DMU level which is less experienced when dealing with public sector than with private sector which can lead to flexibility in data interpretation prompting the researcher to move and seek for data from system to sub-systems which might even result to increase in research knowledge through pertinent questions and further justification from responsible officials for whatever inefficiencies are uncovered (Charnes, Cooper & Rhodes, 1978). The objective is to measure the efficiency of resource utilized in whatever combinations are present in the organization as well as the techniques utilized in whatever combinations are present as well as the technologies utilized and to evaluate the accomplishments or resource conservation possibilities. Considering the fact that competition, free and diverse deployment of resources from one industry to another the introduction of prices or weighting devices, for the evaluation of otherwise non-comparable alternatives. Their measures was not designed for this kind of application but was designed for public sector programs in which the managers of various DMU's are not free to divert resources to other programs merely because they are more profitable or otherwise more attractive.

3. Methodology

Gap analysis is usually used as the basic method in performance evaluation and benchmarking. This is concerned with one measure at a time (Zhu, 2003). This study makes use of the variable-benchmark models. A DMU is not just assumed to be a benchmark but must pass through some analysis and comparisons with other DMUs in order to obtain the efficiency gaps between the DMU and other DMUs before it is concluded as a benchmark, such analysis is as follows:

$$\begin{aligned} & \min \delta_1^{CRS} \\ & \text{subject to} \\ & \sum_{j=1}^{n} \lambda_j x_{ij} \leq \delta_1^{CRS} x_i^{new} \qquad i = 1,2,\ldots,m; \\ & \sum_{j=1}^{n} \lambda_j y_{rj} \leq y_r^{new} \qquad r = 1,2,\ldots,s \\ & \lambda_j \geq 0,\ j \in E^* \qquad j = 1,2,\ldots,n \end{aligned} \tag{1}$$

$$\begin{aligned} & \max \tau_1^{CRS} \\ & \text{subject to} \\ & \sum_{j=1}^{n} \lambda_j x_{ij} \leq x_i^{new} \qquad i = 1,2,\ldots,m; \\ & \sum_{j=1}^{n} \lambda_j y_{rj} \leq \tau_1^{CRS} y_r^{new} \qquad r = 1,2,\ldots,s \\ & \lambda_j \geq 0,\ j \in E^* \qquad j = 1,2,\ldots,n \end{aligned} \tag{2}$$

The above input variable-benchmark models measures the performance of DMU^{new} i.e. Lagos Port Complex with inputs x_i^{new} and outputs y_r^{new}. The superscript of CRS indicates that the benchmark frontier composed by benchmark DMUs in set E^* exhibit CRS. Model 5.4 and 5.5 yields a benchmark for DMU^{new} *i.e.* Lagos Port Complex with inputs x_i^{new}.

Conditions for the Ports:

If δ_1^{CRS*} is less than 1 or τ_1^{CRS} is greater than 1 then the performance of port is dominated by the benchmark

If δ_1^{CRS*} is equal to 1 or τ_1^{CRS} is equal to 1 then the performance of Lagos Port Complex achieve the same performance level of the benchmark.

If δ_1^{CRS*} greater than 1 or τ_1^{CRS} less than 1 then input savings or output surpluses exists in Lagos Port Complex when compared to the benchmark thus making it a new benchmark by overriding the old one.

$\delta^{CRS*} > 1$ *indicates that* DMU^{new} *can increase its inputs to reach the benchmark which in turn indicates that* $\delta^{CRS*} - 1$ *measures the input saving achieved by* DMU^{new}. *Also* $\delta^{CRS*}\tau^{CRS*} < 1$ *indicates that* DMU^{new} *can reduce its outputs to reach the benchmark*

Furthermore, the DEA solver determines the benchmark terminal by comparing the terminal's efficiency with other terminal operators' efficiencies and its efficiency. If the terminal has 1 against itself the DEA efficiency implies it is 100% efficiency.

4. Results and discussion

4.1. Analysis of sensitivity of Nigerian ports with respect to input quantities

Table 2: Input quantities for Lagos Port Complex

NO	DMU	Score	(Number of berth)	(Average turnaround time)	(Average berth occupancy rate)	(Average throughput)	(Ship Traffic)
1	1990	0.94	-1	-1.3	-2	0	0
2	1991	0.98	0	-0.3	-1	0	0
3	1992	0.85	-4	-3.1	-5	0	0
4	1993	0.90	-3	-1.5	-5	0	0
5	1994	0.83	-4	-0.9	-11	0	0
6	1995	0.97	-1	-0.4	-1	0	0
7	1996	0.95	-1	-0.4	-2	0	0
8	1997	0.94	-2	-0.5	-2	0	0
9	1998	0.90	-3	-0.9	-4	0	0
10	1999	0.82	-5	-1.8	-6	0	0
11	2000	0.89	-3	-1.5	-3	0	0
12	2001	1.00	0	0.0	0	0	0
13	2002	0.96	-1	-0.9	-1	0	0
14	2003	0.96	-1	-0.8	-1	0	0
15	2004	1.00	0	0.0	0	0	0
16	2005	0.93	-2	-0.9	-3	0	0
17	2006	0.97	-1	-0.3	-1	0	0
18	2007	0.92	-2	-0.8	-3	0	0
19	2008	0.94	-2	-0.5	-2	0	0
20	2009	0.95	-1	-0.3	-2	0	0
21	2010	1.00	0	0.0	0	0	0
22	2011	1.00	0	0.0	0	0	0
23	2012	0.92	-2	-0.6	-3	0	0
24	2013	0.95	-1	-0.3	-2	0	0
25	2014	0.94	-2	-0.3	-3	0	0

Source: Author's Computation

From the Table 2, the level of inputs required for each DMU to be efficient is given i.e. for DMU 2014 to be efficient input-wise, the number of berth may be reduced by two units as a result of idleness of this two (2) berths, the average turnaround time may be reduced by 3 hours and the berth occupancy may be reduced by 3%. Since a fixed asset such as berth cannot be reduced therefore technically and complimentarily the turnaround time and berth occupancy rate need to be decreased more than 5hours and 3% respectively by allocating the queue ship at the over-utilized berth to the idle berths which in turn will mitigate underutilization of this berths been required to be reduced or alternatively the Port should embrace more cargo handling technology to enhance fast loading and discharging of cargoes thus attracting more vessels to the Port.

The Table 3 depicts the actual level of inputs used and projected level of inputs to be used to achieve the specific level of outputs at Tin Can Island Port. Thus, it is observed that the Port was most technically efficient (DMU/year 2014) when specific levels of outputs were achieved i.e. 1692 Ship calls and reconciled throughput of 17,500,804 tons with optimized levels of inputs i.e. 18 working berths, average turnaround time of 4.3, average berth idle rate of 35.3 and labour rate of 12 gang per hour.

Table 3: Input quantities for Tin Can Island Port Complex

DMU	Score	Actual (NOB)	Project. (NOB)	Actual (ATT)	Project. (ATT)	Actual (ABIR)	Project. (ABIR)	Actual (NG/H)	Projection (NG/H)	Actual (AT)	Project. (AT)	Actual (ST)	Project. (ST)	DMU
1	2015	1.0		18		4.0		56.1		15.0		16881845		1656
2	2014	1.0		18		4.3		35.3		12.0		17500804		1692
3	2013	1.0		18		4.5		31.6		13.0		16134153		1621
4	2012	1.0		18		5.0		29.2		12.0		15136436		1609
5	2011	1.0		18		5.0		28.9		15.0		15371000		1628
6	2010	1.0		17		4.1		33.3		11.4		16551117		1607
7	2009	0.9		16		3.8		31.0		10.6		15390778		1488
8	2008	0.9		15		3.4		33.4		10.4		14083276		1367
9	2007	0.8		13		3.0		25.1		8.5		12251964		1185
10	2006	0.6		10		2.6		17.3		7.5		8888482		903
11	2005	0.4		7		1.7		14.0		4.8		6940331		671
12	2004	0.5		7		1.8		14.5		4.9		7198912		696
13	2003	0.5		9		2.0		16.8		5.7		8315985		804
14	2002	0.4		7		1.6		13.1		4.6		6510729		633
15	2001	0.9		14		3.4		28.0		9.5		13898000		1344
16	2000	0.7		11		2.7		22.2		7.5		11008278		1064
17	1999	0.5		9		2.0		16.7		5.7		8281342		801
18	1998	0.5		8		1.9		15.8		5.4		7832112		757
19	1997	0.4		7		1.7		13.7		4.6		6774838		655
20	1996	0.5		8		2.0		16.0		5.5		7953971		769
21	1995	0.4		6		1.5		12.3		4.2		6102526		590
22	1994	0.5		7		1.7		14.0		4.8		6961017		673
23	1993	0.4		5		1.3		10.4		3.5		5150946		498
24	1992	0.4		5		1.3		10.6		3.6		5233692		506
25	1991	0.5		7		1.6		12.7		4.3		6319735		611
26	1990	0.4		6		1.5		12.1		4.1		5999094		580
27	1989	0.4		6		1.3		10.8		3.7		5357811		518
28	1988	0.4		6		1.3		10.9		3.7		5399184		522
29	1987	0.4		5		1.3		10.6		3.6		5264722		509
30	1986	0.4		6		1.4		11.3		3.8		5606050		542
31	1985	0.4		6		1.4		11.6		3.9		5740512		555
32	1984	0.4		6		1.4		11.5		3.9		5678452		549
33	1983	0.4		6		1.3		10.9		3.7		5409527		523
34	1982	0.3		5		1.1		9.4		3.2		4675156		452
35	1981	0.4		5		1.2		10.1		3.4		4995797		483
36	1980	0.4		5		1.2		10.0		3.4		4933737		477

Source: Author's Computation

Table 4: Input quantities for Delta Port Complex

DMU	IO-CRS TE Score	Actual (NOB)	Project (NOB)	Actual (ATT)	Project (ATT)	Actual (ABIR)	Project (ABIR)	Actual (NG/H)	Project (NG/H)	Actual (AT)	Project (AT)	Actual (ST)	Project (ST)
1985	1.0	20	20	6.6	6.6	75.0	75.0	10	10.0	1,954,000	1954000	409	409
1995	1.0	20	20	4.4	4.4	85.0	85.0	11	11.0	1,947,000	1947000	450	450
1998	1.0	20	20	6.3	6.3	83.5	83.5	16	16.0	2,107,991	2107991	576	576
2009	1.0	23	23	9	9.0	92.0	92.0	15	15.0	7,345,000	7345000	328	328
2013	1.0	23	23	3.9	3.9	88.8	88.8	22	22.0	10,361,746	10361746	609	609
2014	1.0	23	23	5.4	5.4	84.1	84.1	28	28.0	10,199,169	10199169	603	603
1997	1.0	20	20	6.4	5.1	85.7	84.0	13	12.9	1,960,736	2001749	498	498
1980	1.0	20	19	6.9	4.7	72.6	71.3	23	22.6	2,111,000	7865076	509	509
2015	1.0	23	20	3.5	3.4	87.0	77.0	20	19.1	7,830,236	8983583	528	528
1981	1.0	20	17	6.1	4.9	71.0	68.0	17	16.3	2,045,000	3923546	475	475
1996	0.9	20	18	6.47	5.7	84.1	76.0	19	14.6	1,940,044	1940044	524	524
2010	0.9	23	20	8	3.4	89.5	78.3	28	19.4	9,142,000	9142000	337	537
1993	0.9	20	18	5.2	4.5	84.0	73.7	13	11.4	1,957,000	1957000	435	435
1982	0.9	20	17	5.7	5.0	82.3	71.4	20	14.5	1,973,000	3067733	492	492
1994	0.9	20	17	5.7	4.9	83.8	70.5	17	14.3	1,822,000	3030321	486	486
1992	0.8	20	16	6.1	5.0	82.2	67.8	15	12.4	1,690,000	1701521	452	452
1984	0.8	20	16	5.4	4.4	79.0	64.7	13	10.6	1,886,000	1886000	397	397
2011	0.8	23	19	7	3.2	89.8	72.6	25	18.0	8,467,000	8467000	362	498
1986	0.8	20	15	6.3	4.6	78.0	62.0	16	12.7	1,735,900	2132958	429	429
1983	0.8	20	14	5.9	4.2	73.0	57.7	16	12.6	1,930,000	2536741	401	401
1987	0.8	20	15	5.5	4.1	78.3	58.9	19	14.3	1,640,300	3665290	412	412
1991	0.7	20	15	4.8	3.6	83.5	59.6	18	13.1	1,526,000	4209096	410	410
2001	0.7	20	14	6	4.3	84.7	60.0	27	11.8	1,855,000	2043782	414	414
2012	0.7	23	16	5.7	3.1	84.6	60.9	20	14.4	6,808,884	6808884	357	391
1988	0.7	20	14	5.3	3.8	79.1	56.9	21	13.8	1,645,400	3914887	397	397
1989	0.7	20	14	5.7	4.0	80.5	56.6	24	12.9	1,658,200	2997800	394	394
1999	0.7	20	14	5.7	4.0	83.0	57.8	20	11.7	1,394,223	2481621	398	398
1990	0.7	20	14	5.9	4.1	82.0	56.4	28	11.7	1,504,000	2289111	390	390
2002	0.7	20	14	6	4.0	83.9	56.0	20	11.1	2,043,000	2043000	386	386
2005	0.6	20	13	6	3.6	91.7	52.4	29	10.6	2,223,000	2223000	361	361
2000	0.6	20	12	6	3.4	83.2	48.0	24	9.6	1,837,000	1837000	331	331
2003	0.6	20	12	8	3.3	89.9	47.4	26	9.5	1,886,000	1886000	327	327
2004	0.5	20	10	8	3.1	90.0	43.2	18	8.6	1,566,000	1566000	298	298
2008	0.5	23	11	7	2.3	90.4	43.8	21	10.2	4,002,000	4002000	301	301
2007	0.5	23	10	6	2.4	83.5	37.9	29	12.6	1,516,000	4600620	272	272
2006	0.4	23	9	7	2.6	92.0	36.8	25	8.7	1,461,000	2025379	257	257

Source: Author's Computation

The Table 3 depicts the actual level of inputs used and projected level of inputs to be used to achieve the specific level of outputs at Delta Port. The Port was most technically efficient year 1998 and 2013 when 576 Ship calls and reconciled throughput of 2,107,991tons was achieved with optimized levels of inputs i.e. either 20 working berths, average turnaround time of 6.3, average berth idle rate of 83.5 and labour rate of 16.0 gang per hour or in year 2013 when the Port achieved 609 Ship calls and reconciled throughput of 10,361,746 tons was achieved with optimized levels of inputs i.e. either 23 working berths, average turnaround time of 3.9, average berth idle rate of 88.8 and labour rate of 22.0 gang per hour.

The Table 5 depicts the actual level of inputs used and projected level of inputs to be used to achieve the specific level of outputs at Rivers Port. Thus, it is observed that the Port was most technically efficient (DMU/year 2001) when specific levels of outputs were achieved i.e. 432 Ship calls and reconciled throughput of 5,690,000 tons with optimized levels of inputs i.e. 8 working berths, average turnaround time of 12 days, average berth idle rate of 20%, and labour rate of 14 net gang per hour.

The Table 6 depicts the actual and projected level of inputs to be used to achieve the specific level of outputs. Thus, it is observed that the most efficient level of operation is either when the Port operated on 6 berths, average turnaround time of 3 days, average berth idle rate of 29%, labour rate of 29 ng/h to achieve throughput of 13,809,000 tons and 585 ship calls or when she operated on 7 berths, average turnaround time of 5.6 days, average berth idle rate of 64%, labour rate of 15 ng/h to achieve throughput of 17,462,000 and ship calls of 670.

Table 5: Input Quantities for Rivers Port Complex

NO	DMU	IO-CRS TE Score	Actual (NOB)	Project. (NOB)	Actual (ATT)	Project. (ATT)	Actual (ABIR)	Project. (ABIR)	Actual (NG/H)	Project. (NG/H)	Actual (AT)	Project. (AT)	Actual (ST)	Project. (ST)
1	1996	1.0	8	8	9.3	9.3	42	42.0	11	11.0	4,110,962	4,110,962	402	402
2	2001	1.0	8	8	12	12.0	20	20.0	14	14.0	5,690,000	5,690,000	432	432
3	2002	1.0	8	8	14	14.0	10	10.0	15	15.0	5,302,000	5,302,000	394	394
4	2003	1.0	8	8	17	17.0	6	6.0	20	20.0	4,845,000	4,845,000	362	362
5	2009	1.0	11	11	10.4	10.4	25	25.0	18	18.0	5,185,000	5,185,000	465	465
6	2011	1.0	11	11	10.2	10.2	39	39.0	16	16.0	7,464,000	7,464,000	566	566
7	2013	1.0	11	11	7.7	7.7	52.1	52.1	14	14.0	4,935,944	4,935,944	439	439
8	2014	1.0	11	11	8.41	8.4	53.6	53.6	14	14.0	6,225,008	6,225,008	435	435
9	1995	1.0	8	8	7.7	7.6	67	27.7	21	11.7	4,621,000	5,406,363	410	410
10	2010	1.0	11	9	9.7	9.6	30	29.7	14	13.9	5,797,000	6,220,014	471	471
11	1998	1.0	8	8	13	11.9	30	19.8	14	13.9	4,652,600	5,637,315	428	428
12	1989	1.0	8	8	17	11.8	49	19.7	19	13.8	5,597,700	5,597,700	420	425
13	1988	1.0	8	8	14	11.8	51	19.6	22	13.7	4,224,300	5,584,630	424	424
14	1997	1.0	8	8	10	8.5	38	37.0	11	10.7	3,819,966	4,263,178	388	388
15	1985	1.0	8	8	18	11.5	52	19.2	15	13.4	4,533,100	5,466,088	415	415
16	2000	1.0	8	8	11	10.5	26	20.9	24	12.9	4,684,000	5,401,608	410	410
17	2015	1.0	11	9	6.9	6.6	62.3	37.5	17	11.4	4,458,010	4,458,010	373	373
18	1994	1.0	8	7	8.2	6.7	43	25.5	11	10.5	4,880,000	4,880,000	345	370
19	1987	0.9	8	8	15	9.6	56	22.3	13	12.3	4,716,999	5,297,504	402	402
20	1999	0.9	8	8	9	8.4	32	23.9	16	11.7	4,369,000	5,180,363	393	393
21	2006	0.9	11	8	12	11.2	21	19.7	18	13.9	5,580,000	5,580,000	257	419
22	2012	0.9	11	9	8.9	8.3	37.7	35.1	15	13.3	5,574,281	5,950,803	461	461
23	1984	0.9	8	7	16	10.9	47.5	18.2	17	12.8	4,282,000	5,189,491	394	394
24	2007	0.9	11	7	9.99	9.1	21	19.1	23	11.8	4,879,000	4,879,000	339	367
25	1986	0.9	8	7	14	10.9	44	18.1	18	12.7	4,560,023	5,163,148	392	392
26	1992	0.9	8	7	14	10.8	50	18.0	16	12.6	3,724,000	5,123,634	389	389
27	1983	0.9	8	7	11.9	10.5	41.8	17.8	20	12.3	4,057,000	5,018,391	381	381
28	1990	0.9	8	7	11	9.6	42	19.1	24	11.8	3,445,000	4,927,321	374	374
29	2005	0.9	11	8	13	11.3	20	17.4	28	13.6	5,347,000	5,347,000	353	401
30	1982	0.9	8	7	13.4	10.4	34	17.3	18	12.1	3,760,000	4,912,894	373	373
31	1993	0.9	8	7	10	8.6	55	20.4	13	11.2	4,453,000	4,810.001	365	365
32	1991	0.8	8	7	9	7.5	47	21.2	15	10.4	3,345,000	4,600,373	349	349
33	2008	0.8	11	8	9.57	7.7	34	27.4	25	12.3	4,885,000	5,299,245	412	412
34	1980	0.8	8	6	15	9.7	47	16.1	22	11.3	4,000,000	4,583,611	348	348
35	1981	0.8	8	6	18	9.0	42	15.0	14	10.5	3,841,000	4,280,671	325	325
36	2004	0.6	11	7	17	10.5	28	17.4	22	12.2	4,964,000	4,964,000	212	377

Source: Author’s Computation

Table 6: Input Quantities for Onne Port Complex

No	DMU	Score	Actual (NOB)	Project (NOB)	Actual (ATT)	Project (ATT)	Actual (ABIR)	Project (ABIR)	Actual (NG/H)	Projection (NG/H)	Actual (AT)	Project (AT)	Actual (ST)	Project (ST)
1	2004	1.0	6	6	3	3.0	26	26.0	33	33.0	13,688,000	13,688,000	579	579
2	2005	1.0	6	6	3	3.0	29	29.0	29	29.0	13,809,000	13,809,000	585	585
3	2007	1.0	7	7	2	2.0	30	30.0	17	17.0	21,559,000	21,559,000	411	411
4	2008	1.0	7	7	5	5.0	66	66.0	14	14.0	21,419,000	21,419,000	457	457
5	2009	1.0	7	7	5.6	5.6	64	64.0	15	15.0	17,462,000	17,462,000	670	670
6	2010	1.0	10	10	2.7	2.7	65	65.0	11	11.0	23,302,000	23,302,000	785	785
7	2011	1.0	10	10	4	4.0	63.2	63.2	15	15.0	26,217,000	26,217,000	885	885
8	2012	1.0	10	10	2.5	2.5	67.6	67.6	13	13.0	26,532,187	26,532,187	861	861
9	2013	1.0	10	10	2.6	2.6	75.4	66.3	12	12.0	24,773,387	24,917,093	823	823
10	2014	1.0	10	10	2.2	2.2	71.5	71.5	15	15.0	27,968,861	27,968,861	847	847
11	2006	1.0	6	6	2	2.0	29	28.9	15	15.0	15,820,000	15,820,000	433	433
12	2015	1.0	10	9	2.1	2.1	88	67.6	18	14.2	26,434,660	26,434,660	741	801
13	2003	0.8	6	5	3	1.9	28	21.9	34	19.6	11,995,000	11,995,000	398	398
14	2002	0.7	6	4	8	2.1	29	21.2	32	21.1	10,182,000	10,182,000	423	423
15	2001	0.7	6	4	4	2.6	55.6	30.6	17	11.2	9,056,487	9,723,855	378	378
16	2000	0.5	6	3	4	1.7	51	16.2	28	14.9	7,166,000	7,363,972	310	310
17	1980	0.5	6	3	3.8	1.7	72	16.9	27	14.2	4,820,000	7,338,745	307	307
18	1999	0.5	6	3	4.3	2.1	47	24.3	15	7.8	4,353,428	7,716,975	294	294
19	1990	0.5	6	3	6.4	1.9	65	20.7	21	10.4	3,723,200	7,120,952	287	287
20	1981	0.5	6	3	4.1	1.7	65	17.3	25	12.2	4,200,000	6,898,611	285	285
21	1983	0.5	6	3	3.2	1.6	70.3	20.6	16	7.8	3,501,000	7,241,691	271	271
22	1995	0.5	6	3	4.7	1.4	72	19.8	10	4.7	5,195,000	7,276,059	254	254
23	1982	0.5	6	3	3.5	1.6	61	19.7	18	8.4	3,759,000	6,842,858	264	264
24	1991	0.4	6	3	4.8	1.8	75	20.2	19	8.5	3,681,000	6,530,362	260	260
25	1998	0.4	6	3	5	1.7	52	18.5	27	9.5	6,440,000	6,440,000	260	260
26	1986	0.4	6	3	5.9	2.1	59	23.4	14	6.2	3,200,000	6,574,965	254	254
27	1984	0.4	6	3	4.4	1.7	65.6	18.7	20	8.6	3,262,000	6,216,049	249	249
28	1985	0.4	6	2	5.2	2.0	62	22.7	13	5.4	3,068,000	6,223,688	239	239
29	1988	0.4	6	2	3.2	1.3	58	16.3	19	7.8	2,560,000	6,016,894	232	232
30	1989	0.4	6	2	2.8	1.1	50	16.5	15	6.0	1,880,000	6,049,853	221	221
31	1996	0.4	6	2	4.8	1.4	63	14.7	24	9.5	5,208,568	5,626,384	231	231
32	1992	0.4	6	2	5.3	1.5	67	16.4	21	8.2	3,856,000	5,632,251	227	227
33	1997	0.4	6	2	3.4	1.3	59	18.5	32	4.8	5,926,219	5,926,219	210	210
34	1987	0.4	6	2	3	1.1	53	14.6	17	6.1	2,340,000	5,355,748	201	201
35	1993	0.3	6	2	3.4	1.2	92	16.7	11	3.8	3,603,000	5,268,958	189	189
36	1994	0.3	6	2	3.8	0.5	78	14.2	33	3.0	5,407,000	5,407,000	158	158

Source: Author's Computation

Table 7: Input Quantities for Calabar Port Complex

NO	DMU	IO-CRS TE Score	Actual (NOB)	Project (NOB)	Actual (ATT)	Project (ATT)	Actual (ABIR)	Project (ABIR)	Actual (NG/H)	Project (NG/H)	Actual (AT)	Project (AT)	Actual (ST)	Project (ST)
1	1985	1.0	12	12	6.2	6.2	85.9	85.9	10	10.0	575,000	575,000	420	420
2	2007	1.0	12	12	2.0	2.0	75.5	75.5	20	20.0	1,042,000	1,0420,00	682	682
3	2008	1.0	12	12	4.0	4.0	72.7	72.7	23	23.0	1,165,000	1,165,000	622	622
4	2014	1.0	12	12	5.4	5.4	66.5	66.5	26	26.0	2,361,477	2,361,477	269	269
5	2015	1.0	12	12	5.2	5.2	77	77.0	22	22.0	2,127,421	2,127,421	306	306
6	2013	1.0	12	11	6.8	4.4	63.3	63.1	23	22.7	1,732,286	1,732,286	373	373
7	2012	0.9	12	10	5.6	4.2	75.4	62.9	19	18.0	1,738,446	1,738,446	159	250
8	1987	0.9	12	11	5.5	5.2	92	77.7	12	11.3	695,700	695,700	412	412
9	2009	0.9	12	11	4.0	3.7	76.5	65.6	24	22.0	1,699,000	1,699,000	198	410
10	2011	0.9	12	11	5.3	4.6	77.3	68.0	21	19.4	1,880,000	1,880,000	179	270
11	2006	0.9	12	11	3.0	1.8	79.9	67.6	23	17.9	777,000	933,522	611	611
12	2005	0.9	12	10	2.0	1.7	79.5	65.3	21	17.3	900,624	900,624	508	589
13	1986	0.9	12	10	6.8	3.6	89.1	69.5	15	12.9	716,500	716,500	465	465
14	2010	0.8	12	9	4.6	3.6	77.1	53.1	27	19.0	1,588,000	1,588,000	199	284
15	2004	0.7	12	9	5.0	1.5	79.1	55.9	25	15.0	798,717	798,717	499	499
16	2001	0.7	12	9	6.0	3.5	85.3	59.3	13	9.3	328,335	512,015	357	357
17	1989	0.7	12	7	4.2	3.0	89.6	47.4	11	7.7	485,000	485,000	267	267
18	2003	0.7	12	8	5.0	1.4	82.5	53.1	23	14.1	506,252	733,372	480	480
19	1998	0.7	12	8	5.2	3.6	91.3	55.6	11	7.7	216,308	430,732	306	306
20	1999	0.6	12	8	4.5	2.8	81.3	51.7	14	8.9	223,943	483,735	333	333
21	2002	0.5	12	7	6.0	1.1	84	41.3	20	10.9	409,219	569,891	373	373
22	2000	0.5	12	6	3.0	1.6	83.3	41.4	17	9.2	311,765	489,014	326	326
23	1997	0.5	12	5	4.7	2.4	96	35.8	9	4.7	90,643	263,500	189	189
24	1992	0.5	12	6	4.7	1.9	92.1	41.3	16	8.3	416,261	443,009	299	299
25	1984	0.5	12	5	4.0	1.8	76	34.0	13	6.0	243,155	323,310	222	222
26	1982	0.4	12	5	6.2	0.9	88	33.5	23	8.9	426,433	462,941	303	303
27	1995	0.4	12	5	3.9	1.7	93	33.3	14	6.1	171,449	331,234	226	226
28	1981	0.4	12	5	5.7	1.0	86.3	30.4	19	7.5	403,411	403,411	257	257
29	1988	0.4	12	5	3.7	1.2	84.6	30.2	19	7.4	444,700	444,700	233	233
30	1994	0.4	12	4	3.4	0.7	93.9	27.0	23	7.2	363,400	372,798	244	244
31	1983	0.4	12	4	4.8	1.3	79	28.0	16	5.7	263,186	302,560	204	204
32	1996	0.3	12	4	6.1	1.3	94.9	27.9	16	5.6	101,928	299,290	202	202
33	1980	0.3	12	4	4.1	1.4	80	27.6	15	5.2	164,578	279,104	190	190
34	1993	0.3	12	3	4.0	0.5	93.2	19.6	24	5.2	254,000	270,431	177	177
35	1991	0.2	12	3	4.3	0.5	92.8	18.3	28	4.8	201,000	252,097	165	165
36	1990	0.2	12	3	3.8	0.4	93.5	15.8	24	4.2	118,446	218,484	143	143

Source: Author's Computation

However, in year 1994 which is the least year the Port was supposed to operate on 2 berths instead of 6 berths, average turnaround time of 0.5 days instead of 3.8 days, average berth idle rate of berth idle 14.2% instead of 78%, labour rate of 3ng/h instead of 33ng/h to achieve throughput of 5,407,000 tons and ship calls of 158. In other words, berth idle rate would have been minimized if the 4 idle berths were utilized thereby reflecting scale optimization. Hence turnaround was supposed to be reduced if necessary, cargo equipment were put in place with the appropriate average labour rate of 3ng/h instead of 33ng/h used. This reflects huge waste at the Port at pre-concession era.

The Table 7 depicts the actual and projected level of inputs to be used to achieve the specific level of outputs. Thus, it is observed that the Port was most technically efficient (DMU/year 2007) when specific levels of outputs were achieved i.e. 682 Ship calls and reconciled throughput of 1,042,000 tons with optimized levels of inputs i.e. twelve (12) working number of berths, average turnaround time of 2.0, average berth idle rate of 75.5 and labour rate of 20 gang per hour. However, the practice(s) adopted in the year 2007 is the best practice for other operation years in Calabar Port. The best practice DMU was a year after the concessioning of the said Port thus, the best performance may be as a result of the involvement of the concessionaires and the zeal deployed by these private concessionaires towards the terms of lease.

It is inferentially observed that the Port lacked technicality in the pre-concession years which had negative impacts on the scale size of the Port i.e. in year 1990 which is one of the least inefficient operation years at Calabar Port with score 0.2, the Port should have achieved 143 Ship calls and throughput of 118,446 tons with minimized inputs of three (3) berths, 0.4 days average turnaround time, 15.8% average berth idle rate and 4.2ng/h labour rate. Since berth is a fixed asset and cannot be reduced or minimized on a short run however, ship traffic should have been allocated to the underutilized berths to reduce idle rate of berth and cost of underutilization. Hence, it seems there were very low market or ship call at this port which may be as a result of underutilization or marginalization of the port in Nigerian Port industry.

Conclusion

In the pre-concession era, all Nigerian Ports had trouble achieving a reasonable outputs quantities with minimal inputs' quantities. However, there were improvements in the productivities of these Ports in the post concession era even though only Onne Port had significant improved productivity from the year of concessioning year 2004 through increased efficiency and maintained the change till year 2015. This reflects the well-being of the Port after the concession and the positive impacts of the private operators on the productivity of the Port in terms of technology and inputs mix. Calabar Port had been under-utilized towards the achievement of the required results. On the contrary, Rivers Port requires technical touches in her operations. As a liquid bulk port, the time of loading and discharging of commodities are often more than any other types of port and the turnaround time at this port are often more. Scale optimization is also required in Rivers Port. Inferentially, Lagos Port has been operating on optimal scale size but fluctuating managerial efficiency were experienced in the operation years which could be as a result of exogenous factors which some scholars mentioned to have been necessary superstructure, political factors, port dues e.t.c. As a matter of findings, Tin Can Island has similar trend to that of Onne Port with low productivities in the pre-concession period which improved consistently in the post-concession year of 2010 till year 2015. It was also observed that Tin Can Island Port operated on under-utilization of inputs resources in the pre-concession periods till the post-concession year 2010. This reflect element of wastefulness with respects to both inputs and outputs quantities. Delta Port experienced fluctuating scale and technical efficiency trend in both pre and post concession years. Hence, it is observed that productivities' trends vary among the concessioned Nigerian Ports. These could be as a result of influence of varied exogenous and endogenous factors on individual port.

Citation information

Nze, O. N., & Ejem, A. E. (2020). Sensitivity analysis of performance of Nigerian ports using data envelopment analysis. *Journal of Sustainable Development of Transport and Logistics, 5*(1), 37-47. doi:10.14254/jsdtl.2020.5-1.4.

References

Hajizadeh, A., Saeidi, S. N., Kaabi, A., Yousefi, H., & Zaredoost, M. (2017). Relative efficiency analysis of container ports in Middle East using DEA. *Journal of Marine Science and Technology*, *15*(4), 69-80.

Kaiser, E., Pathomsiri, S., & Haghani, A. (2006). *Developing measures of US ports productivity and performance: using DEA and FDH approaches* (No. 1427-2016-118553).

Lin, W. C., Liu, C. F., & Chu, C. W. (2005). Performance efficiency evaluation of the Taiwan's shipping industry: an application of data envelopment analysis. In *Proceedings of the Eastern Asia Society for Transportation Studies* (Vol. 5, No. 1, pp. 467-476). Citeseer.

Talley, W. K. (2009). Port Economics. In W. K. Talley, *Port Economics* (p. 17). Virginia: Taylor & Francis e-Library.

van Dyck, G. K., & Ismael, H. M. (2015). Multi-criteria evaluation of port competitiveness in West Africa using analytic hierarchy process (AHP). *American Journal of Industrial and Business Management*, *5*(06), 432.

Zhu, J. (2003). Quantitative Models for Performance Evaluation and Benchmarking; Data Envelopment Analysis with Spreadsheets and DEA Excel Solver. In J. Zhu, *Envelopment Model; Envelopment Models with Variable Returns to Scale* (pp. 5-11). New York: Springer International Series Operations Research Management Science.