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# Evaluate and Analysis Efficiency of Safaga Port Using DEA-CCR, BCC and SBM Models – Comparison with DP World Sokhna

Ayman Elsayed<sup>1</sup>, Nabil Shabaan Khalil<sup>2</sup>

<sup>1</sup> Harbors Engineering and Marine Structures, Cairo, Egypt

<sup>2</sup> General Manager of projects- RSPA, El-Suez, Egypt

dr\_aymanz@yahoo.com

**Abstract.** The competition among maritime ports is increasing continuously; the main purpose of Safaga port is to become the best option for companies to carry out their trading activities, particularly importing and exporting. The main objective of this research is to evaluate and analyze factors that may significantly affect the levels of Safaga port efficiency in Egypt (particularly the infrastructural capacity). The assessment of such efficiency is a task that must play an important role in the management of Safaga port in order to improve the possibility of development and success in commercial activities. Drawing on Data Envelopment Analysis (DEA) models, this paper develops a manner of assessing the comparative efficiency of Safaga port in Egypt during the study period 2004-2013. Previous research for port efficiencies measurement usually using radial DEA models (DEA-CCR), (DEA-BCC), but not using non radial DEA model. The research applying radial - output oriented (DEA-CCR), (DEA-BCC) and non-radial (DEA-SBM) model with ten inputs and four outputs. The results were obtained from the analysis input and output variables based on DEA-CCR, DEA-BCC and SBM models, by using software Max DEA Pro 6.3. DP World Sokhna port higher efficiency for all outputs were compared to Safaga port. DP World Sokhna position is below the southern entrance to the Suez Canal, on the Red Sea, Egypt, makes it strategically located to handle cargo transiting through one of the world's busiest commercial waterways.

## 1. Introduction

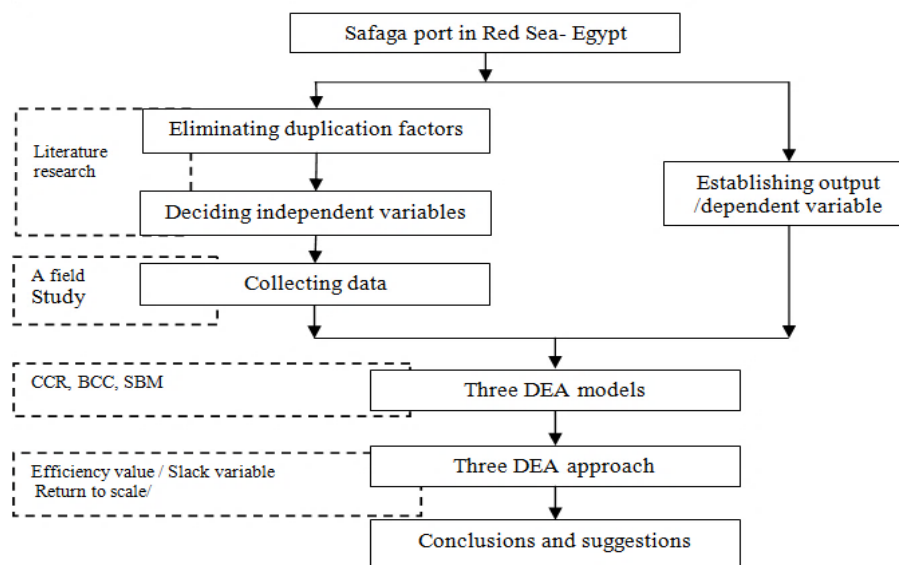
The efficiency measurement of Safaga Port - Egypt is necessary for continuous improvement, to avoid shortcomings and failures. Analysis of port efficiency provides operators with clear ideas about the extent to which a port's resources are employed and helps them to compare their advantages and disadvantages. Safaga port has land area 878 000 m<sup>2</sup>, includes 4 quays 1341 m long, between 10 to 14m depth and Passenger terminals 37 000 m<sup>2</sup>. Non-parametric approaches use linear programming to determine the efficiency frontier. One mathematical programming technique is commonly applied to estimate the efficient frontier. They are data envelopment analysis (DEA) is used to determine the efficiency of port and to observe the possibility of changes in the port efficiency over time. A study is conducted to evaluate the efficiency of port in order to identify the sources of inefficiencies and formulate proposals for improving the services of those ports and their operations.

## 2. Methodology

Data envelopment analysis (DEA) has been invented by Charnes et al (1978) [1], this technique is based on linear programming and it will convert the input and output variable to linearity technique for measuring the efficiency. This conversion is based on the inputs and outputs for its decision making units (DMU). In DEA model, standard CCR measures the constant returns to scale whereas standard BCC measures the variable return to scale efficiencies. The application of DEA can be classified into



input-oriented and output-oriented. There are two models for measuring efficiency in DEA, radial and non-radial, which can evaluate the efficiency of Safaga port (DMUs). Radial models assume proportional change of inputs or outputs and usually disregard the existence of slacks in the efficiency scores. A new non-radial model by the name of slacks-based measure (SBM) was developed by Tone, [2]. SBM model directly works with input excess and output shortfall slacks, and integrates them into an efficiency measure, it has been commonly used to evaluate efficiency of port production systems. We use output-oriented CCR and BCC models to analyze how to produce the maximum possible throughput from a given fixed quantity of resources used to analyze Safaga port in Red Sea.



**Figure 1.** Flow Chart of Research Methodology

## 2.1. The Basic Models of DEA

### 2.1.1. The DEA-CCR output oriented model

The output oriented model, which aims to maximize outputs while not exceeding the observed input levels [3].

$$\begin{aligned} \min q_o &= \sum_{i=1}^m v_i x_{io} \\ \text{s.t. } \sum_{r=1}^s u_r y_{ro} &= 1 \quad \sum_{i=1}^m v_i x_{ij} - \sum_{r=1}^s u_r y_{rj} \geq 0 \quad j = 1, \dots, n \quad u_i, v_r \geq \varepsilon \\ i &= 1, \dots, m, \quad r = 1, \dots, s \end{aligned} \quad (1)$$

And the dual for it is formulated as:

$$\begin{aligned} \max z_o &= \phi + \varepsilon \cdot \sum_{r=1}^s s_r^+ + \varepsilon \cdot \sum_{i=1}^m s_i^- \\ \text{s.t. } \phi \cdot y_{ro} - \sum_{j=1}^n \lambda_j \cdot y_{rj} + s_r^+ &= 0 \quad r = 1, \dots, s \\ \sum_{j=1}^n \lambda_j \cdot x_{ij} + s_i^- &= x_{io} \quad i = 1, \dots, m \\ \lambda_j, s_i^-, s_r^+ &\geq 0 \quad j = 1, \dots, n, \quad i = 1, \dots, m, \quad r = 1, \dots, s \end{aligned} \quad (2)$$

### 2.1.2. DEA-BCC output oriented model

The objective in BCC-O is to maximize the output production while not exceeding the actual input level.

$$\begin{aligned} \max z_o &= \phi + \varepsilon \cdot \sum_{r=1}^s s_r^+ + \varepsilon \cdot \sum_{i=1}^m s_i^- \\ \text{s.t. } \phi \cdot y_{ro} - \sum_{j=1}^n \lambda_j \cdot y_{rj} + s_r^+ &= 0 \quad r = 1, \dots, s \end{aligned} \quad (3)$$

$$\sum_{j=1}^n \lambda_j \cdot x_{io} + s_i^- = x_{io} \quad i = 1, \dots, m$$

$$\sum_{j=1}^n \lambda_j = 1$$

$$\lambda_j, s_i^-, s_r^+ \geq 0 \quad j = 1, \dots, n, i = 1, \dots, m, r = 1, \dots, s$$

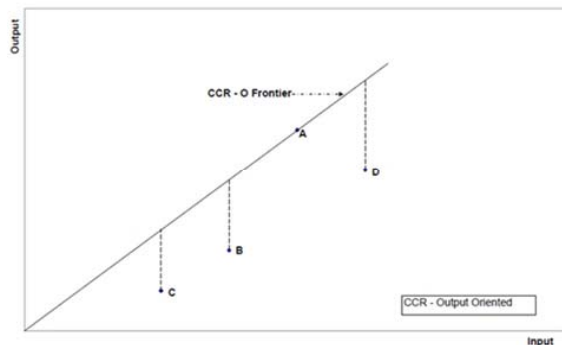


Figure 2. DEA-CCR output oriented model

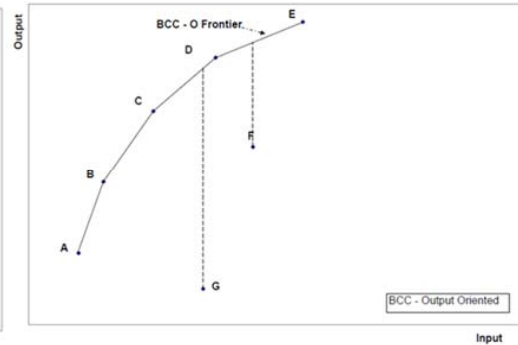


Figure 3. DEA-BCC output oriented model

## 2.2. A slack-based measure model of efficiency (DEA-SBM)

Previous research on ports' efficiency usually adopts both DEA - CCR and DEA- BCC model, but not used slacks-based measure (SBM) [4]. DEA-SBM model are non-radial and can deal with inputs and outputs individually. The purpose of this model is to minimize the input and output slacks, resulting in this fractional program, which is converted to a linear program before solving [5].

A DMU  $(x_o, y_o) \in p$  is called CRS-efficient if any solution of the system

$$\min_{\lambda, \delta^-, \delta^+} \quad \rho = \min \quad \frac{1 - \frac{1}{m} \sum_{i=1}^m \frac{\delta_i^-}{x_{io}}}{1 + \frac{1}{s} \sum_{r=1}^s \frac{\delta_r^+}{y_{ro}}} \quad (4)$$

where:  $s^+ = s^-$  Subjected to  $X_o = X\lambda + s^-$ ,  $Y_o = Y\lambda - s^+$

$$\lambda \geq 0, \quad s^- \geq 0, \quad s^+ \geq 0$$

## 2.3 Returns to scale evaluation and scale efficiency

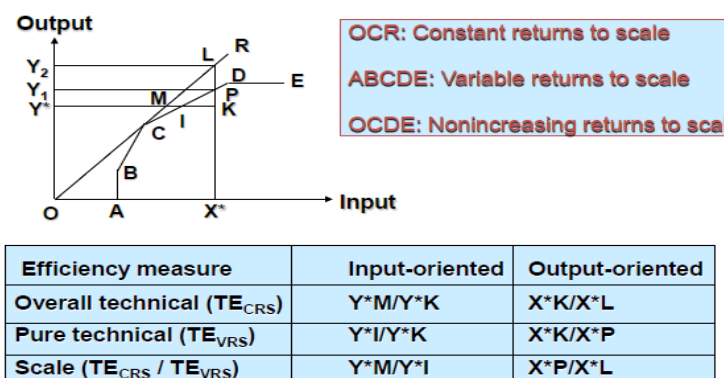
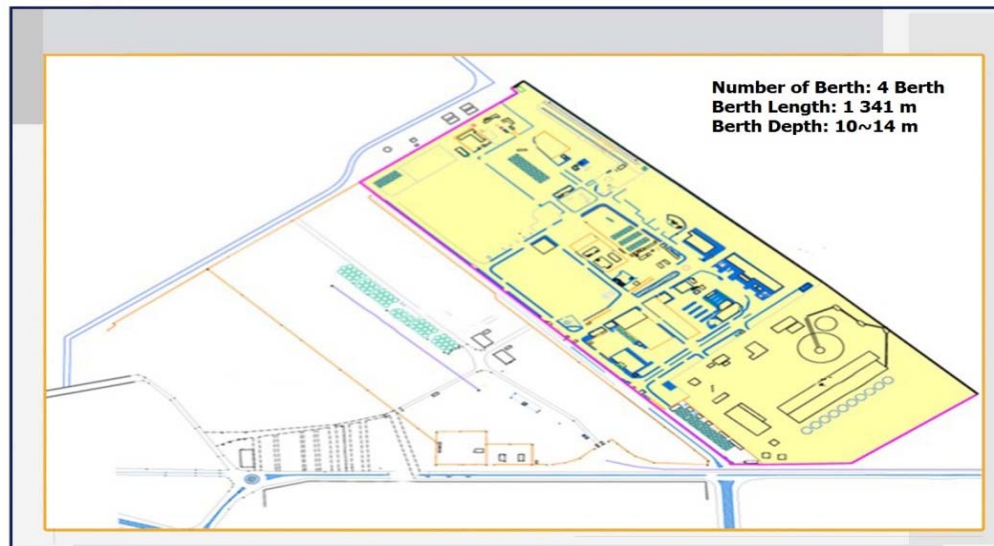


Figure 4. Returns to scale and efficiency in DEA

### 3. A field Study to Measure the Current Operating Efficiency of the Safaga port

There is no system in Safaga port for efficiency measurement, whether electronic or manual, but use of so-called performance indicators, which help to take decisions. The focus is on the number of vessel calling the port and the total volumes handled, which are currently used in measuring performance of the port as a whole. Manager of port review a number of ships and total volumes handled over the years and measure any increase or decrease as an indicator to assess the performance of the port. There is no formal efficiency measurement system in place applied in Egyptian ports.



**Figure 5.** Layout of Safaga port

#### 3.1. Discussion of the data collection process

The data collection process is an integral part of the research design and it aims to collect accurate and reliable data using different sources. Six sources for data collection using a case study strategy. These are documentation, archival records, interviews, direct observation and participant Observation and port visits. Red Sea Ports Authority provided to the researcher statistical data available for the containers, cargo handling, and movement of passengers, tourists and ships call from 2004 to 2013 as shown in the following tables 4.1.

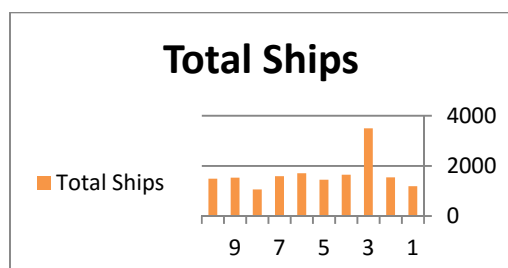
#### 3.2. Measuring the current performance efficiency applied in Safaga port

##### 3.2.1. A number of calling ships

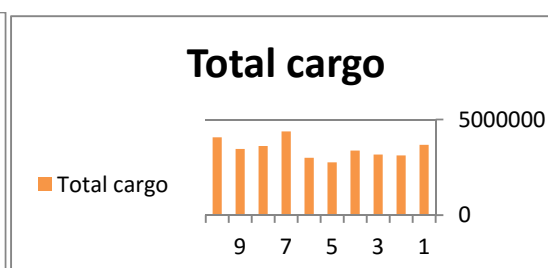
Relative efficiency analysis of calling ships in Safaga port as follows [6]:

The degree efficiency for calling ships in year =

$$\frac{\text{The number of calling ships the previous year} \times 1.10}{\text{The number of calling ships the previous year} \times 1.10} \quad (5)$$



**Figure 6.** Total Calling Ships in Safaga port



**Figure 7.** Total cargo handling in Safaga port

##### 3.2.2. Total cargo handling in Safaga port

Relative efficiency of general cargo in Safaga port as follows, the degree efficiency of Safaga port in cargo handling = total number of containers for the previous year  $\times 1.10$

**Table 1.** Descriptive statistics of the cargo input and output variables during (2009-2013).

Year	Port	Output			Input								
		Cargo	No. of berth	Berth length	Land Area	Fixed Cranes	Yard Cranes	Water Area	Storage	Terminal	Depth of Berth	Passenger Station	Labour
2009	Al-Sokhna	12145304	6	2350	1000000	6	6	55000000	20000	100000	17	0	800
	Suez, Adabia	7283205	29	4738	4317000	0	3	162500000	200000	50000	12	8000	426
	Safaga	2993713	6	1400	878000	0	0	57000000	0	150000	14	37000	153
	Noybaa	729220	4	380	340000	0	0	10000000	0	50000	8	20100	82
	Sharm Al-Shiekh	0	1	625	160000	0	0	88000000	0	10000	8	4000	36
	Hurghada	0	3	335	43000	0	0	10000000	0	5000	10	15000	33
2010	Al-Sokhna	11472994	6	2350	1000000	6	6	55000000	20000	100000	17	0	900
	Suez, Adabia	7049272	29	4738	4317000	0	3	162500000	200000	50000	12	8000	426
	Safaga	4373772	6	1400	878000	0	0	57000000	0	150000	14	37000	153
	Noybaa	852764	4	380	340000	0	0	10000000	0	50000	8	20100	82
	Sharm Al-Shiekh	0	1	625	160000	0	0	88000000	0	10000	8	4000	36
	Hurghada	0	3	335	43000	0	0	10000000	0	5000	10	15000	33
2011	Al-Sokhna	9623546	6	2350	1000000	6	6	55000000	20000	100000	17	0	1000
	Suez, Adabia	4521162	29	4738	4317000	0	3	162500000	200000	50000	12	8000	426
	Safaga	3613225	6	1400	878000	0	0	57000000	0	150000	14	37000	153
	Noybaa	787831	4	380	340000	0	0	10000000	0	50000	8	20100	82
	Sharm Al-Shiekh	0	1	625	160000	0	0	88000000	0	10000	8	4000	36
	Hurghada	0	3	335	43000	0	0	10000000	0	5000	10	15000	33
2012	Al-Sokhna	12303856	6	2350	1000000	6	6	55000000	20000	100000	17	0	1100
	Suez, Adabia	4398809	29	4738	4317000	0	3	162500000	200000	50000	12	8000	426
	Safaga	3459498	6	1400	878000	0	0	57000000	0	150000	14	37000	153
	Noybaa	963121	4	380	340000	0	0	10000000	0	50000	8	20100	82
	Sharm Al-Shiekh	0	1	625	160000	0	0	88000000	0	10000	8	4000	36
	Hurghada	0	3	335	43000	0	0	10000000	0	5000	10	15000	33
2013	Al-Sokhna	12120167	6	2350	1000000	6	6	55000000	20000	100000	17	0	1200
	Suez, Adabia	7807936	29	4738	4317000	0	3	162500000	200000	50000	12	8000	426
	Safaga	4061658	6	1400	878000	0	0	57000000	0	150000	14	37000	153
	Noybaa	847263	4	380	340000	0	0	10000000	0	50000	8	20100	82
	Sharm Al-Shiekh	0	1	625	160000	0	0	88000000	0	10000	8	4000	36
	Hurghada	0	3	335	43000	0	0	10000000	0	5000	10	15000	33

### 3.3. Flow information process

Safaga port handles all type of cargo. The following (for example) is an overview of the port operations from the vessel intimation, berthing, loading/unloading of export cycle operations – General cargo till the sailing out of the vessel [7].

## 4. Analysis efficiency of Safaga port using DEA models

The flow process of multiple DEA analyses can be depicted as shown in figure 10, figure 11 to 13 and table 2 presented the efficiency of Safaga Port according to models of DEA-BCC, DEA-CCR and SBM during the analysis period with Comparison to DP world Sokhna:

1. Average efficiency of general cargo according to models of DEA-BCC, DEA-CCR and SBM are 0.39, 0.29 and 0.20. Average Scale efficiency is 0.74, while Average efficiency of DP world Sokhna for general cargo according to models of DEA-BCC, DEA-CCR and SBM are 0.67, 0.55 and 0.27. Average Scale efficiency is 0.82.
2. Average efficiency throughput (passengers) according to models of DEA- BCC, DEA-CCR and SBM are 0.44, 0.28 and 0.19. Average scale efficiency is 0.63, while Average efficiency of DP world Sokhna for throughput (passengers) according to models of DEA- BCC, DEA-CCR and SBM are 0.19, 0.14 and 0.09. Average scale efficiency is 0.82.
3. Average efficiency calling ships throughput according to models of DEA- BCC, DEA-CCR and SBM are 0.41, 0.31 and 0.23. Average Scale efficiency is 0.75, while Average efficiency of DP world Sokhna for throughput calling ships according to models of DEA- BCC, DEA-CCR and SBM are 0.65, 0.41 and 0.28. Average Scale efficiency is 0.79.



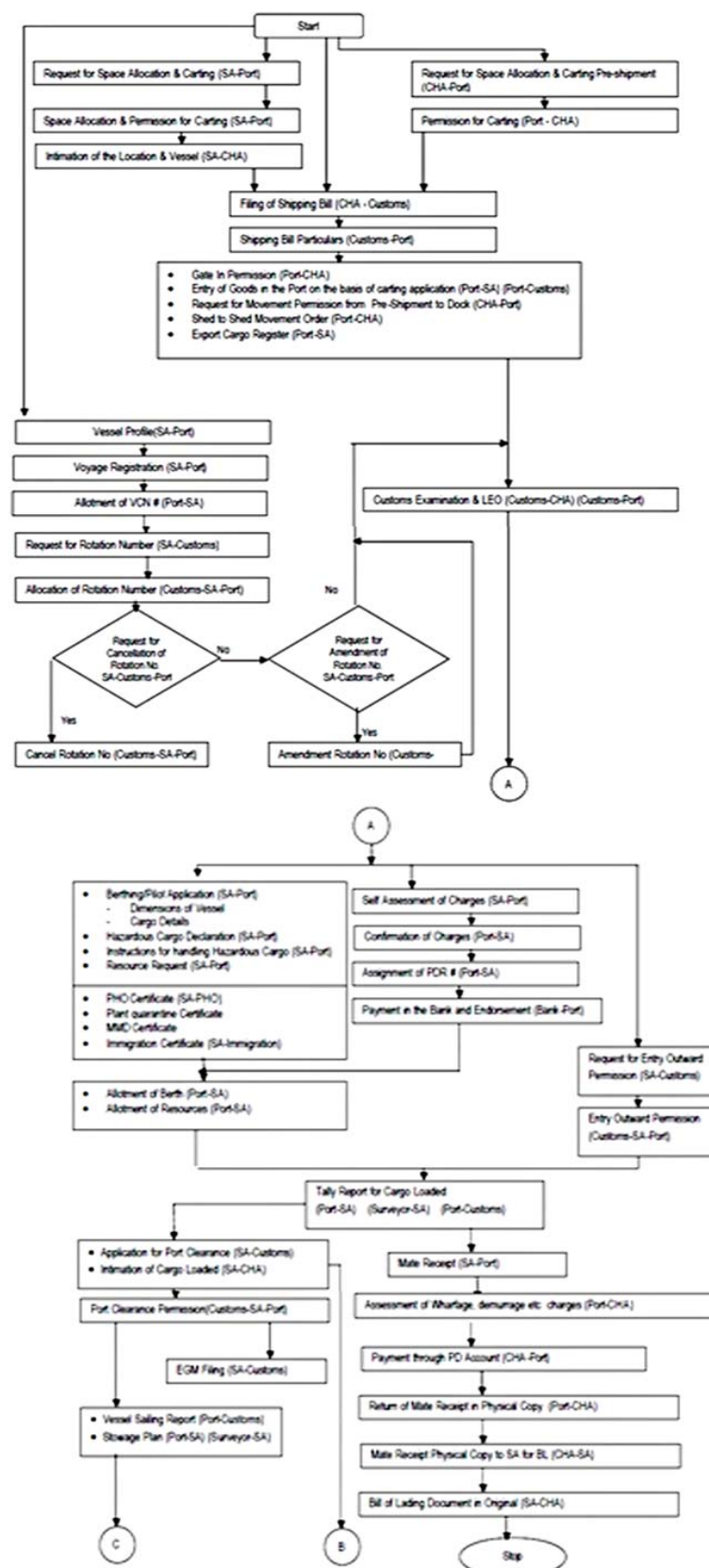
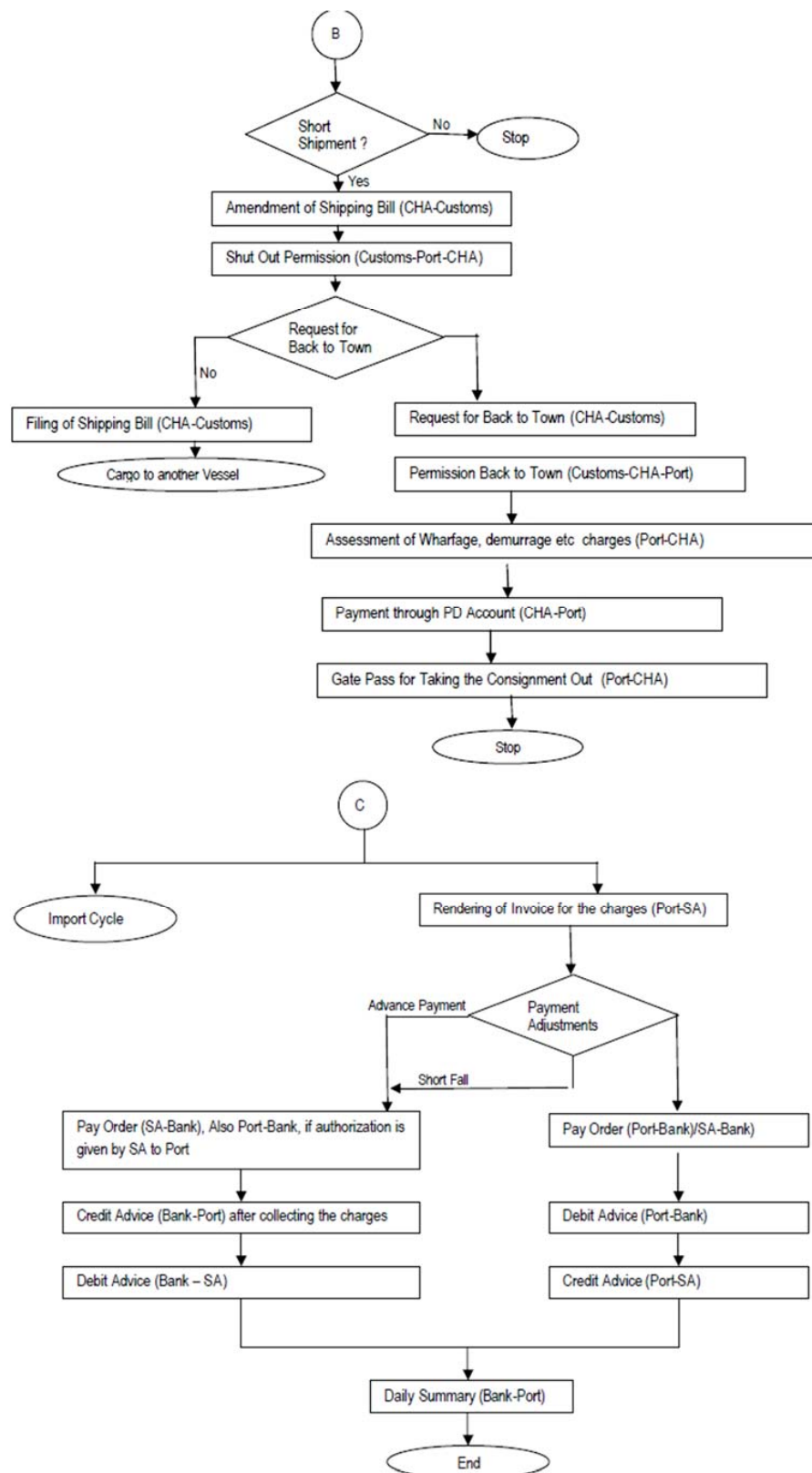


Figure 8. Export cycle operations – General Cargo



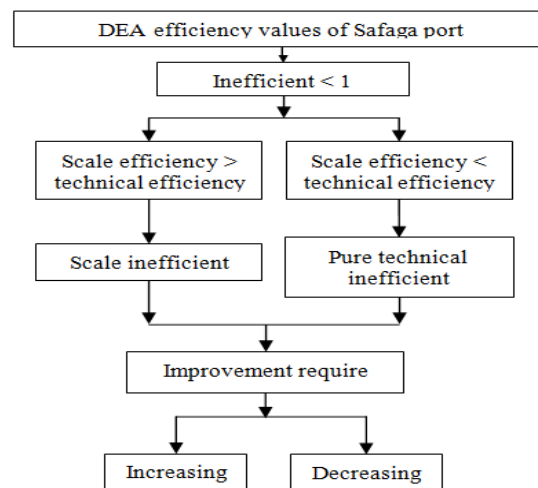
**Figure 9.** Continuous export cycle operations – General Cargo



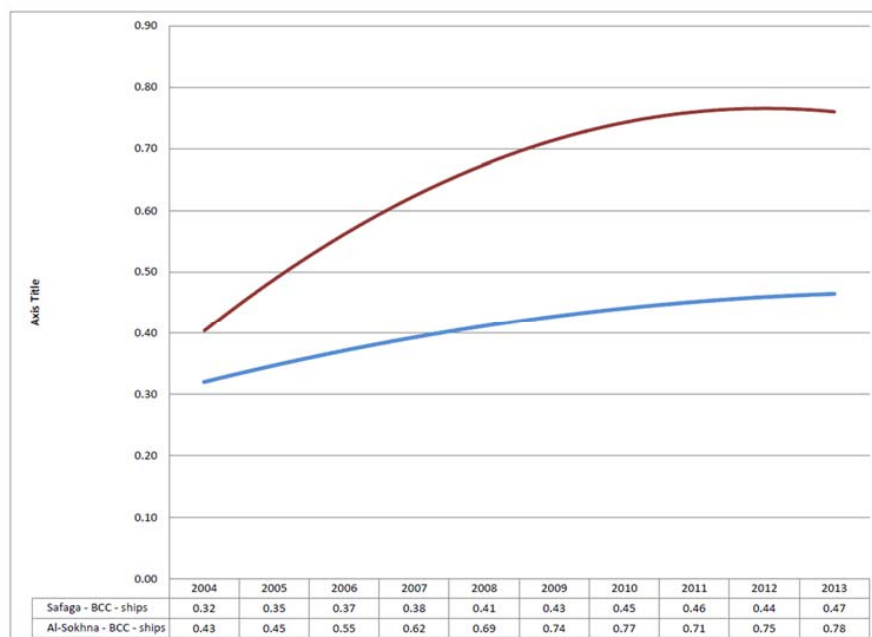
As shown in the figures from 11 to 13 that the DP world Sokhna higher efficiency rates in general cargo handling and calling ships by 85%, 67% than the efficiency rates of the port of Safaga. So efficiency curves of the Sokhna port takes as frontier curves for Safaga port.

Relative efficiency analysis of Safaga Port is less than Relative efficiency analysis of DP world Sokhna in both DEA-CCR, DEA-BCC and SBM models for all throughput, it reflects that the Safaga port has both technical and scale inefficiencies. Table 2 shows that the average efficiency scores during the analysis period reflecting both pure technical and scale inefficiencies in the port.

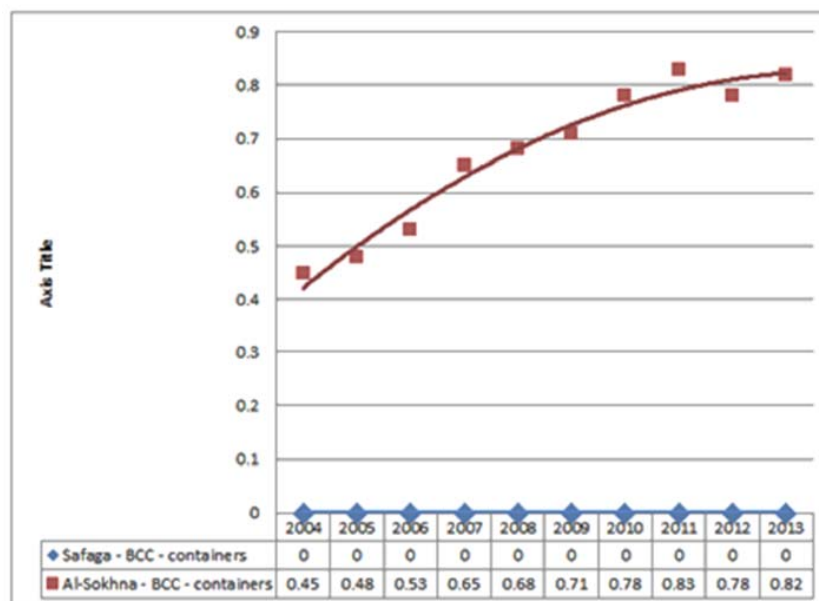
The technical inefficiencies could be the inefficient use of labor and inefficient operations (such as the loading and unloading process of quay-cranes and yard tractors). The general trend of average Safaga port technical efficiencies is downward during the analysis period. It indicates that the production of port fails to keep up with demand in the following years, i.e. Safaga port need to improve the general cargo, passengers, and calling ships throughput and port operations. Safaga port needs the procedures to raise the value of efficiency.



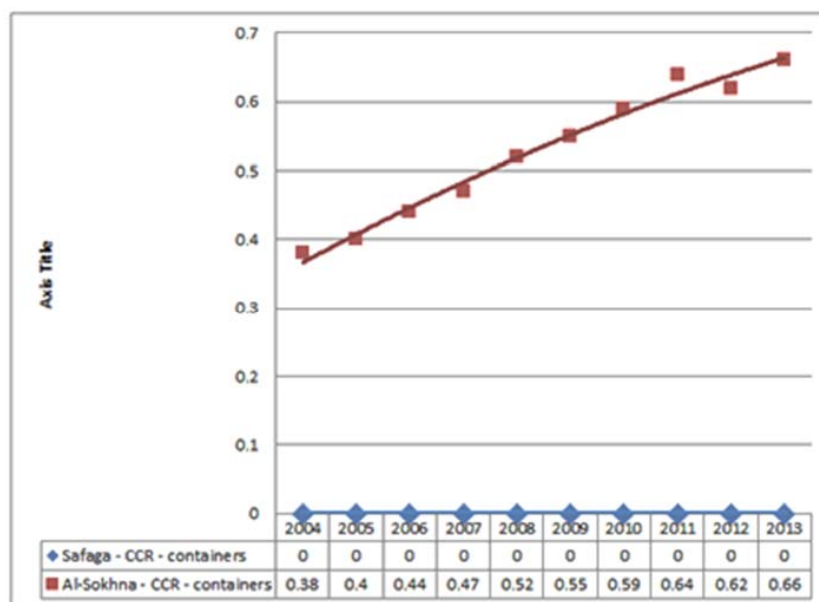
**Figure 10.** Flow process of DEA analyses



**Figure 11.** DEA-BCC of DP Sokhna-Safaga for calling ships



**Figure 12.** DEA- BCC of DP Sokhna-Safaga for container



**Figure 13.** DEA- CCR of DP Sokhna-Safaga for container

### 5. Improves the efficiency of Safaga Port using DEA models

In the DEA-CCR, DEA-BCC and SBM models, Safaga port is considered to be inefficient for the DP World Sokhna due to the lack of berth length, terminal area, covered warehouses, yard waiting for cars and trucks, logistics services, main roads special movement of goods roads and berths area.

Safaga port aims to be efficient and utilization the Strategic location of Safaga port. Using the software Max DEA Pro 6.3. In order to improve and raising the efficiency and scale efficiency by changing the input level of the of Safaga port as following:

1. The ports divided into four terminals (passenger terminal -arenas of the terminal and Exports and imports trucks-general cargo terminal-Yard stores and truck External).

2. Separation between the different axes of movement. Axis movement of passengers, axis movement of goods and axis movement of trucks.
3. The establishment of a multi-purpose berth with fully equipped by 1400 m length, 14 depths as shown in figure 14 and figure 15.

**Table 2.** Efficiency and Scale efficiency of the Safaga port during the Analysis Period

CARGO	YEAR	DEA -BCC	DEA - CCR	DEA - SBM	SCALE EFFICIENCY	RETURNS TO SCALE
	2004	0.28	0.2	0.07	0.714285714	
	2005	0.3	0.24	0.1	0.8	
	2006	0.33	0.29	0.14	0.878787879	
	2007	0.35	0.3	0.16	0.857142857	
	2008	0.41	0.31	0.16	0.756097561	
	2009	0.44	0.33	0.25	0.75	
	20010	0.45	0.34	0.3	0.755555556	
	2011	0.46	0.36	0.27	0.782608696	
	2012	0.43	0.33	0.26	0.76744186	
	2013	0.42	0.29	0.24	0.69047619	

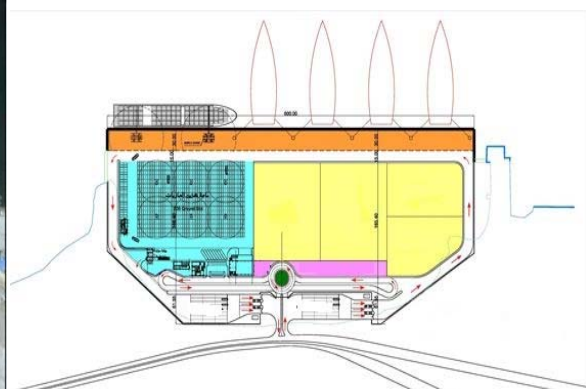
PASSENGER	YEAR	DEA -BCC	DEA - CCR	DEA - SBM	SCALE EFFICIENCY	RETURNS TO SCALE
	2004	0.3	0.21	0.12	0.7	
	2005	0.34	0.23	0.16	0.676470588	
	2006	0.41	0.28	0.19	0.682926829	
	2007	0.45	0.3	0.22	0.666666667	
	2008	0.46	0.32	0.22	0.695652174	
	2009	0.48	0.35	0.28	0.729166667	
	2010	0.49	0.36	0.29	0.734693878	
	2011	0.49	0.29	0.21	0.591836735	
	2012	0.47	0.25	0.13	0.531914894	
	2013	0.48	0.26	0.11	0.541666667	

SHIP	YEAR	DEA -BCC	DEA - CCR	DEA - SBM	SCALE EFFICIENCY	RETURNS TO SCALE
	2004	0.32	0.21	0.11	0.65625	
	2005	0.35	0.26	0.17	0.742857143	
	2006	0.37	0.28	0.19	0.756756757	
	2007	0.38	0.29	0.21	0.763157895	
	2008	0.41	0.31	0.21	0.756097561	
	2009	0.43	0.33	0.24	0.76744186	
	2010	0.45	0.34	0.249345	0.755555556	
	2011	0.46	0.35	0.26	0.760869565	
	2012	0.44	0.34	0.22	0.772727273	
	2013	0.47	0.35	0.23	0.744680851	



**Figure 14.** Proposed location



**Figure 15.** Propose general plan for a multi-purpose berth

## 6. Conclusions and recommendations

Measuring the relative efficiency of ports using DEA has been used. The research has applied radial - output oriented (DEA-CCR), (DEA-BCC) and non-radial (DEA-SBM) for measuring the relative efficiency of Safaga port in Egypt during 2004 – 2013. The selection of input and output variables are based on the variables having close relationship with the efficiency of ports were considered. The input variables has been selected for this study is the number of berths, terminal area, storage, number of equipment, length of berths, total area of port and depth of berths and number of employees whereas output variables are considered in this study is container, Cargo throughput and calling ships.

Based on the results, DP world Sokhnathe highest efficiency from Safaga port, so efficiency curves of the Sokhna port takes as frontier curves for Safaga port. Average efficiency of Safaga port is 0.39 for general cargo, 0.44 for passengers, 0.40 for ships call and 0.74 for scale efficiency. Efficiency scores of Safaga Port is less than DP world Sokhna in both DEA-CCR, DEA-BCC and SBM models for all throughput, it reflects that the port has both technical and scale inefficiencies during the analysis period reflecting the inefficient use of labor and inefficient operations. The efficiency score of Safaga port is less than 1 in DEA-SBM models, it reflects the Safaga port has input excesses and output shortfalls in any optimal solution.

For improving technical efficiency, the technological up gradation should be taken care for the particular ports, the pure technical inefficient values of Safaga port indicating that the most handle application of input resources inefficient. Few suggestions can be made through this study to reinforce the efficiency of Safaga port as following:

1. The port is divided into four terminals (passenger terminal -arenas of the terminal and Exports and imports trucks-general cargo terminal -Yard stores and truck External).
2. Separation between the different axles of movement. Axis movement of passengers, axis movement of goods and axis movement of trucks.
3. The establishment of a multi-purpose berth fully equipped of 1 400 m length, and 14 deep.

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