BENCHMARK AND COMPETITIVE ANALYSIS OF PORT PERFORMANCES MODEL: ALGECIRAS BAY, ROTTERDAM, NEW YORK-NEW JERSEY AND TANGIER MED

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ABSTRACT: *In this research paper four sea ports namely, Tanger Med, Algeciras Bay, Rotterdam and New York-New Jersey has been taken into study to understand and evaluate their efficiency of operations and benchmark them. Port efficiency is the measure of amount of input and output and their ratio. Port efficiency is not solely dependent on port performance. The port performance strategies of the case ports were studied and efficiency variables were found through various literatures. To analyze input and output variables of the ports, efficiency software named Data Envelopment Analysis Program was used to find the most efficient ports. Then the variables for the most efficient ports were benchmarked and ranked. A hypothetical port efficiency model has also been suggested for better efficiency of the ports.*

KEYWORDS: Ports, Efficiency, Benchmark, Performance, DEA

INTRODUCTION

Port Efficiency analysis

Port efficiency analysis is the methodology or the technique used to measure the ratio of input and output of a port(Yang et al., 2011). Port plays a major role in a country's economy and development by providing international trade link, thus their efficiency is vital (Liu, 2010). Port efficiency is an important contributor to an international competitiveness and thus is checked on key performance indicators (KPIs)(UNCAD, 2016). A port need not be efficient alone, but also it needs to be effective in high and quality throughput given to customers; shipper, ship-owners, and carriers.The relationship between demand of port's throughput services and the port process are known as the port's throughput demand function which also influence the port efficiency.There are various factors that affect the efficiency of the ports(Nyema, 2014) like; capital investments, operational services (towing, pilotage, mooring and others), customs clearing time, financial and other vessel operations (avg. turnaround time, avg. vessel calls etc.). Analyzing these factors helps to evaluate the input-output ratio of a particular port.

Container throughput and facility productivity is the main measure and indicator of port performance for every Seaports (Babounia & EL Imrani., 2016). The selection andchoice of the ports by freight carriers are usually based on the feasibility of the sea route, port rates, hinterland connectivity, port infrastructure and port capacity(Ruto & Datche, 2015). Efficient port governance is thereby very important in driving the decisions of the freight carriers which in turn will help the ports to perform well. Physical quantities of items, scale or scope

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of activities, levels of effort expended and the efficiency in converting resources into some kind of product evaluates the efficiency of a Port. In most of the private corporations the outcome measures are evaluated on finances and asset utilization(Mpogolo, 2013). Efficiency focused ports measure their performance on the basis of financial statement, marketing activities of comparison between years and competitors and other similar strategies with the intentions of expanding gross margin (Bozuwa et al., 2012).

Overview of Case Ports

Port of Tanger Med is located in the African country of Morocco is the newest port which opened in FY2007 and has a very strategic location at the slopes of Strait of Gibraltar and the Moroccan coast is nearest to the Iberian Peninsula (Tanger Med Port Authority, 2014). Average ports of call for Africa and Senator Lines are 51 counts(Tanger Med Port Authority, 2016a). The port is committed to quality and environmental approach in maintaining the performance of the port.The port has been reported to handle containers of 0.6million TEU and an operational income of $527,906 for the FY2015. For the FY2016 the total tonnage has been reported to 4.4million TEU(Tanger Med Port Authority, 2016a). Recently, to improve the efficiency of the port, the port authorities have agreed to installation of 68 new industrial projects in Tanger Med complex, along with plans for private investments of $939 million and create 6,547 new jobs(Tanger Med Port Authority, 2016b).These projects will include 13 new industrial units in the automotive sector, 11 units in textile, 2 units in aeronautics, 9 logistics projects and 24 SME (micro, small and medium-sized enterprises) projects.

Port of Algeciras Bay is the oldest and EU’s busiest port and is located at Algeciras Bay and Tarifa, at the southernmost Spain. Port of Algeciras Bay is located between the Atlantic Ocean and the Mediterranean Seais connected to West Africa, Asia, North Europe, and the Americas. Thisport is known for its natural shelter and deep-draft conditions which attracts seafarers (Port of Algeciras Bay, 2015). Average ports of call for APL, Msersk Line and Zim are 160 counts. It was recorded that the total cargo handling for the year 2015 was 4.52million TEUs and a net profit of $941,905(Port of Algeciras Bay, 2016). Port of Algeciras Bay is mainly a transport hub and industrial center along with fishing industry.They have mainly strengthened the port’s logistics and operations by cost reductions, increased port capacity, maritime services and most importantly hinterland connectivity. Moreover, they plan to develop a rolling motorway project to develop a new intermodal service across the Strait of Gibraltar and linking the EU with the North of Africa(Goodwin, 2015). The port authorities plan to achieve and handle more than 5 million TEUs by FY2020. In 2015, the Port of Algeciras received 28,446 ship calls with both the terminals serving more than 3,000 containerships very efficiently(Port of Algeciras Bay, 2016).

Port of Rotterdam, is Europe’s largest sea port, which is located in Netherlands has daily routes to both the TangerMed and Algeciras Bay. The Port of Rotterdam has a busy petrochemical industry and several oil refineries with 209million tonnes of liquid bulk as reported in the FY2015(Port of Rotterdam, 2016a). Crude oil arrives by sea to be processed and delivered to areas in The Netherlands, Germany, and Belgium. The port has also been reported to have handled 461.2 million tonnes in total for the FY2015(Port of Rotterdam, 2016c). The port also handles energy, bio-based, LNG, break bulk, refining and chemicals related cargo. The average port of call for 33 carriers is 72 counts. It has been analyzed that, every year almost 30,000 sea route carrier and 110,000 inland carriers(Port of Rotterdam,

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2016a).The port also aims torise and handle over 15 million TEUs by FY2020 and also to remain the leading port in Europe(Port of Rotterdam, 2016c).

Port of New York and New Jersey is a major port in the USA which is well connected through major sea routes to the other three case ports.The combined port together covers an area of 40,000 meters and consists of small hinterland ports; "*Port Newark, the Howland Hook Marine Terminal, the Red Hook Container Terminal, the Elizabeth Port Authority Marine Terminal*". The port also has 3 cruise terminals for passengers. It was reported that the port had handled 112million tonnes of dry bulk and annual container handled about 3.7million TEU for the FY2015(PONYNJ, 2016). The average port of call for 18 carriers is 62 counts. The Council on Port performance maintains and looks after the port performance and manages them. The council mainly focuses on four main objectives of improvement; equipment, rail, operations and customer care which is reversibly linked by outreaching the government and the community (PONYNJ, 2014).

Table 1: Summary of Case Ports

Features	Port of Tanger Med	Port of Algeciras Bay	Port of Rotterdam	Port of New York-New Jersey
Opening Date	2007	1906	1962	1921
Location	Morocco (Slopes of Strait of Gibraltar and the Moroccan coast is nearest to the Iberian Peninsula)	Algeciras Bay and Tarifa, at the southernmost Spain	Netherlands, near German Ruhr district, Paris and London	New York and New Jersey
Trade Routes	Europe, the Americas, Asia and rest of Africa	West Africa, Asia, North Europe, and the Americas	The Netherlands, Germany, and Belgium	Major sea routes and connectivity with three case ports as well
Ports of Call	51	160	72	62
Complex Includes	Tangier Med 1, 2, Passenger's port and TMPC center	Container terminals, Bulk and break bulk terminals, oil/liquid terminals, Ro/Ro terminals and passenger terminals	Container, Oil, Break bulk, Large Parking Area for transport vehicles, Passenger terminal, Cargo Railway	Passenger terminal, Cargo Airport, Cargo Railway, Container and oil terminals
Handling Capacity	4.4 million TEU	4.52million TEUs	461.2 million tonnes	112 million tonnes of dry bulk and annual container handled about 3.7 million TEU

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Objectives of the Study

The objectives of this research paper are;

a. To investigate the different key performance indicators of the 4 case ports and conduct port efficiency analysis

b. To benchmark ports on different parameters and determine which port is efficient in which area.

METHODOLOGY

Key Performance Indicators

The port's performance is evaluated by checking if actual throughput overcomes optimum throughput (Vitsounis, 2012). Port performance indicators are divided into four categories namely; "*Ship Operations, Cargo Handling, Warehousing, and Inland Transportation*"(Marine Department of Hong Kong, 2006). Port's poor performance depends on dwell time, delay surcharge and ignorance by bigger ships due to insufficient infrastructure.

Container terminals are the main drivers in the operational performance of a port by minimizing ships turnaround time and subsequently maximizing the terminal throughput (Pallis & Syriopoulos, 2007). The yard operations in container terminals is the busiest of all the activities in the terminal (PwC, 2013). Container yard operation's main aim must be to promptly accommodate ships with minimum waiting time in port and with maximum use of berth facilities (Ruto & Datche, 2015).

Quay length is other effective parameters in efficiency of container which scale on the ability to handle more containers per one ship within one quay (Yang et al., 2011). Equipment and machines in quay also contribute to the performance of the ports as they carry out loading and unloading a container from a truck to a vessel or unloading a container from a vessel to a truck or the vice versa (Babounia et al., 2016).

Alongside quay, Berths too are involved in improving the efficiency of the port terminals. Berth's number and length at a container terminal is one of the most important factor the influences the performance and efficiency of the port (Yang et al., 2011).

Efficient cargo handling operations and adequate infrastructure helps avoid congestion and are the indicators of efficient Port Infrastructure which ultimately improves trades and container connectivity of the international trade(Langen et al., 2007). Improved waterfront system, an advancement of infrastructure, includes; reduced human intervention by automatization, low documentation time, Reduced cargo dwell time, Reduced port clearance time, Advanced planning technologies, Ease of statistical data calculations, Enhanced audit trails etc. (Ducruet et al., 2014).

Port dwell time, another influential factor, refers to the time spend by carriers within the port or its extension (Liu, 2010). Cargo dwell time another important influential factior, is defined as the "*time between vessel arrival and container exit from the port facilities and less the average dwell time more efficient is the seaport*"(Slack & Comtoise, 2015; Pg. 3). Speed of

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cargo handling is also very critical as faster ship loading and unloading will raise the ship calls number. Since, the number of terminals is fixed; slow speed will cause the ship to occupy the berth longer, which will delay the next vessel calling and causes a negative impression(Jafari et al., 2013).

Financial indicator is the most important indicator of port performance for most of the ports(UNCAD, 2016). Finance indicators include value added, profit, revenues, return on capital employed and others. Value-added indicators refer to expenses on labour, depreciation and profit, but they are difficult to measure and compare because of the diversity of the activities involved.

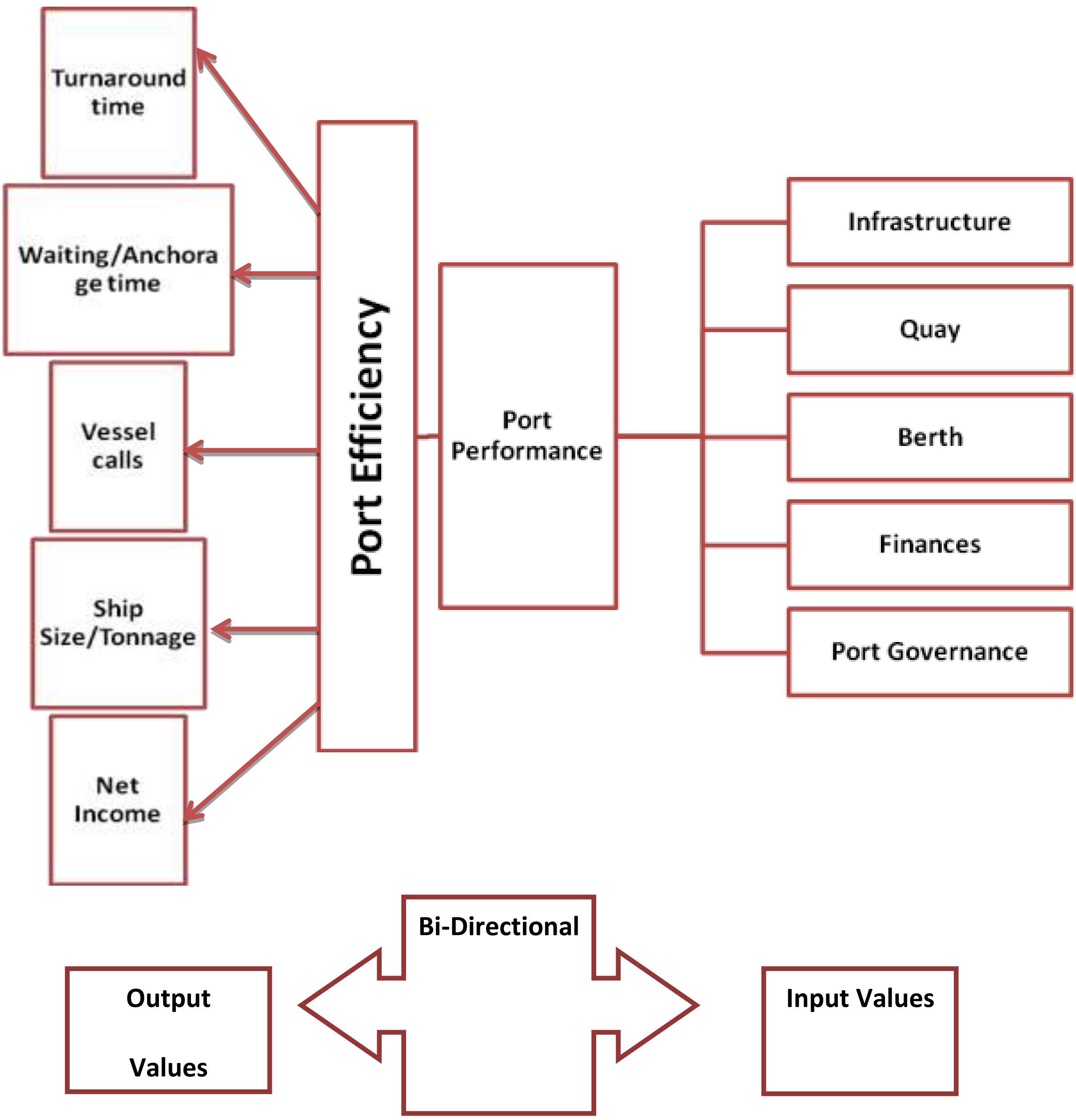

Figure 1: A hypothetical model for Port Efficiency

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Port efficiency is bi-directional as the input and output values towards port performance are equally influential. Input values are applied for high port performance, while the output values show the port efficiency. Many port efficiency models are present according to the literature review.

Measuring Port Efficiency

Commonly used approaches to measure/analyze the efficiency/productivity include, stochastic 17 frontier analysis (SFA), Data Envelopment analysis (DEA), Vector error model (VEM), Corrected original least squares (COLS), Original least squares (OLS)(Beasley, 2017).***Stochastic Frontier Analysis*** is a "*parametric and stochastic approach to estimate productive efficiency of ports*" which is based on the approach that a terminal is efficient if it produces a maximum output variables for a given inputs variables(Dong et al., 2014).Secondly,***Corrected Original Least Squares (COLS)***is also a method of evaluating ports efficiency using the parametric approach. It uses regression methods by calculating an average lineby enclosing the data and correction of the line position. The corrected line can then be measured against this frontier (Bates & Bates, 2007).***Original Least Squares (OLS) Estimation method***basically uses a regression model so that the average line of the data is adjusted(Chun & Keleş, 2010).

However, in this study ***DEA program*** was used to estimate production efficiency(Beasley, 2017). In this approach, the program maps out a production frontier based on information on inputs and outputs. The degree of efficiency is assessed by the distance between the observation and the frontier (Anderson, 2017). The throughput variables are contrasted to check the output performance of the case ports. DEA programs use input and output weights by as the basis of the efficiency calculation and such units can be classified into efficient and inefficient organizations. In inefficient units, the values inform about the amount of input or output variables required to become efficient.

$$Efficiency\ Rate = \frac{\text{weighted sum of outputs}}{\text{weighted sum of inputs}}$$

The input variables used in this are; Infrastructure, Quay, Berths, Financial expenses while, the output variable were; Tonnage, Net Income, Ship Turnaround time, Waiting time and Vessel Calls.The variables were taken from secondary sources like annual reports of case ports and literatures by researchers and shipping companies. Benchmarking of the factors can be done manually by applying graphs and comparing the best performance of the ports in figures. However, benchmarking of the factors cannot be reliable just on figures because it does not show the efficiency measurement. Thus, DEA program was used so that efficiency of the case ports be found and then the factors influencing port efficiency could be benchmarked for the inefficient ports.

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Table 2: Table for the DEA of Input variables

DMU Name	Tanger Med	Algeciras Bay	Rotterdam	New York-New Jersey
Berth Length (meters)	632.4	2124	40000	15000
Berth Nos.	4	8	23	3
Quay Length (meters)	1600	600	89000	30000
Quay Nos.	2	2	12	4
Expenses ($)	433433	2909608	1946974	2900652
Channel (meters)	18	15.2	12.2	13.7
Cargo Pier (meters)	18	12.2	9.1	13.7
Anchorage (meters)	18	23.2	13.7	13.7
Oil Terminal (meters)	18	15.2	10	15.2

Table 3: Table for DEA of output variables

DMU Name	TangerMed	Algeciras Bay	Rotterdam	New York-New Jersey
Income ($)	527906	941905	733035	737005
Average Turnaround time (Days)	2.5	1	0.5	1.5
Average Waiting time (Hours)	14	9	7	10
Average Vessel calls	51	160	72	62
Exports Tonnage (million TEU)	0.92	12.5	5.4	10.6
Import Tonnage (million TEU)	14	39.5	5.7	26.1
Container handled (million Tonnes)	3	4.52	12.23	3.7
Liquid Bulk (million Tonnes)	15.5	25.32	209.4	5.05
Dry bulk (million Tonnes)	2.1	1.6	82.6	112.01
General Cargo (million Tonnes)	111	61.16	6.9	38

(*Note: DMU stands for decision making units and the Efficient Input/output Targets are the variables(Ray, 2008); The ship turnaround time of the ports were taken from Ducruet et al., 2014*)

After the analysis of the performance models of the case ports and subsequent literatures it was found that the benchmarked values for the port's operations are; *average turnaround time, average waiting time, tonnage handled and average vessel calls.*However, there are other important benchmarking values; dwell time, crane moves per hour, time spent at anchorage and others could not be evaluated due to lack of data, hence, the above mentioned factors in table 2 and 3 has been analyzed.

Operational Efficiency of the Case ports

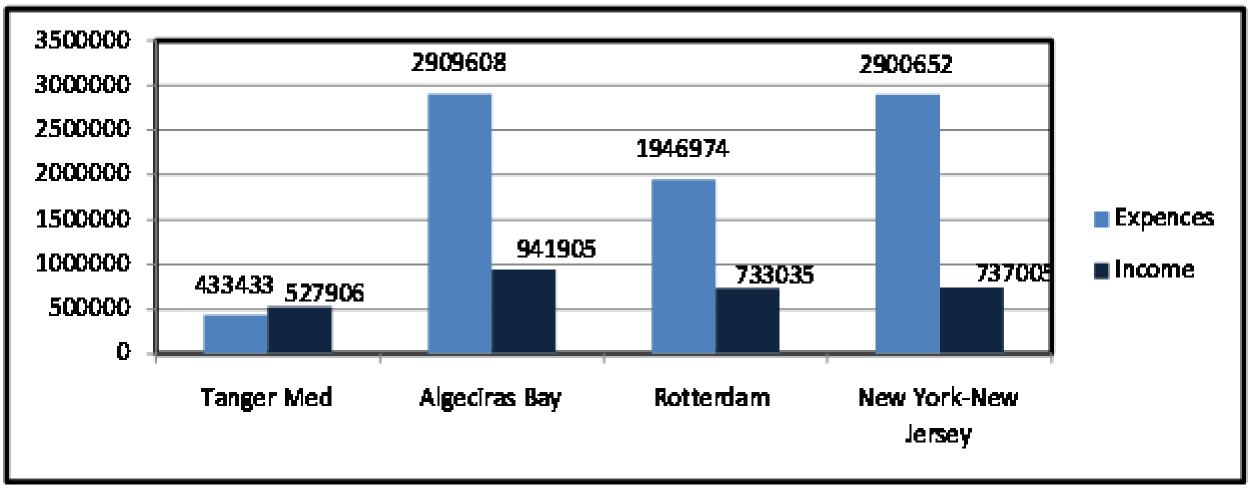
In this section, the performance and the efficiency of the case ports will be interpreted and analyzed. Each output variable was individually analyzed against similar set of input variables. Firstly Ship turnaround time was evaluated against similar input variables; quay and berth, infrastructure, similarly the other output variables were also evaluated accordingly to their input variable.

Contrasting Port Attributes

Expenses and Income ratio of Port Finances

From Figure 2 it can be interpreted that Tanger Med Port is the only one that has surpassed the expense-income ratio (El Imrani & Babounia, 2016). This might implicate that the Tanger Med port has most efficiently used their resources. While others had low income, might be because they did not focus on financial performance.

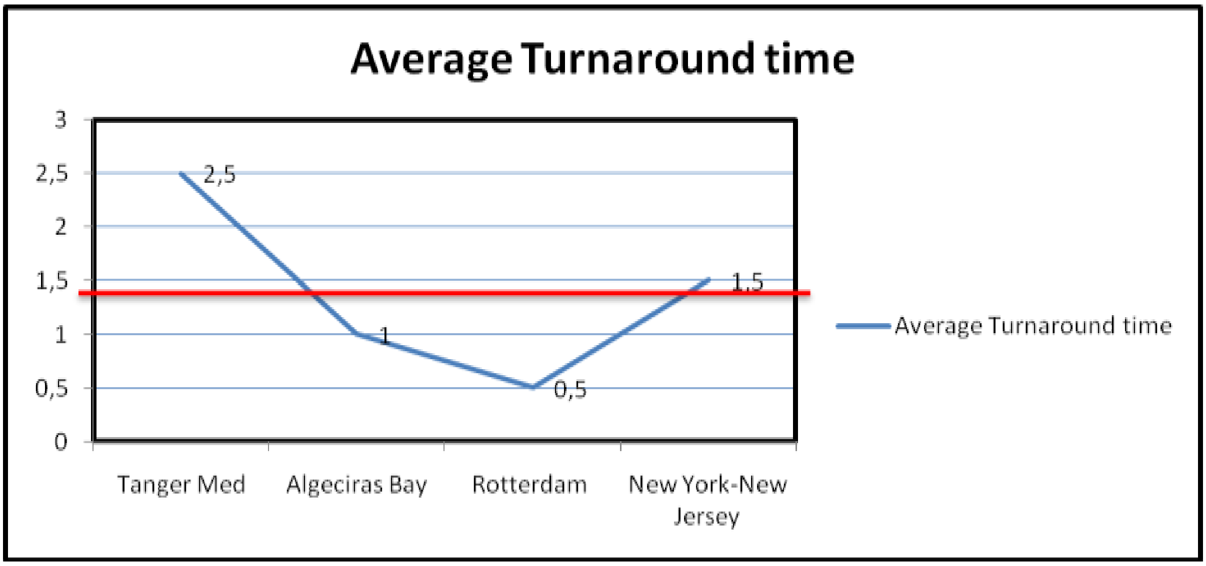
Figure 2: Contrasting the Expenses and Income ratio of Port Finances



Average Turn-around time of Ships

From the Figure 3 it can be seen that the Port of Rotterdam (0.5days) had the least average ship turnaround time (Ducruet et al., 2014). The accepted benchmarked value for the average turnaround time of the case ports was 1.5 days. This means that the Port of Rotterdam, Port of Algeciras Bay and New York-New Jersey port efficiently maintains its terminal operations.

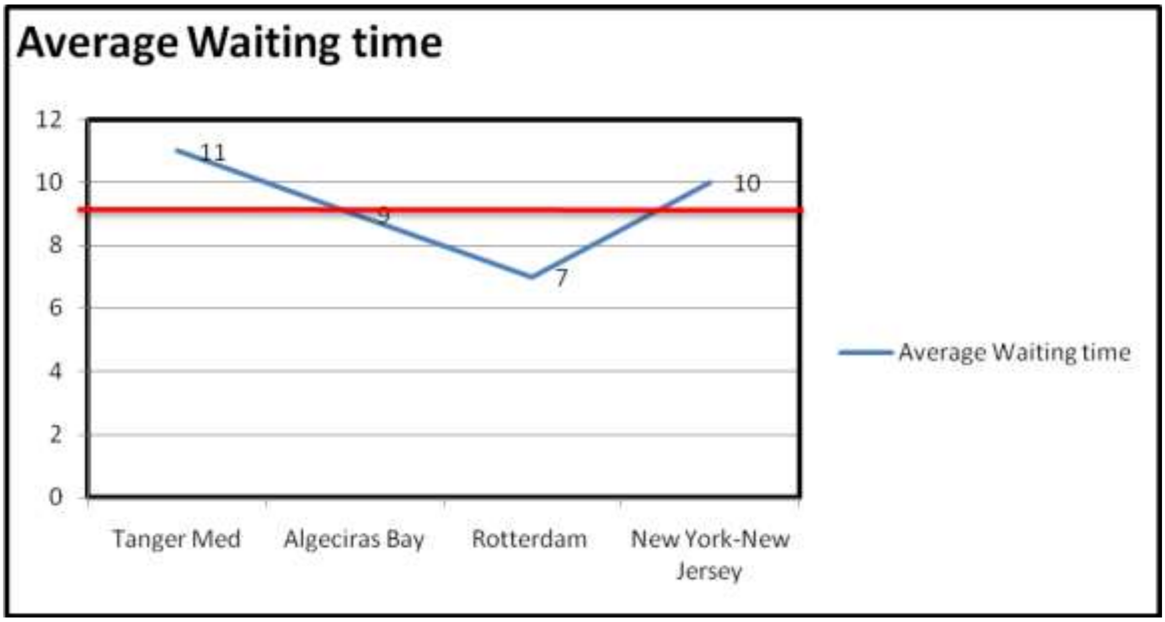
Figure 3: Benchmarking the Average Turnaround time of Ships



Average ship waiting time

From the Figure 4 it can be interpreted that the Ports of Rotterdam (7hrs), Algeciras Bay (9hrs) and NY-NJ (10hrs) has low ship waiting time. The accepted benchmark for the average ship waiting time from the time of call to exit port was 9,25 hours. Tanger Med has high waiting time For two reasons, firstly might be because they have low efficient infrastructure (Ducruet et al., 2014),or, to take advantage of the infrastructure, one of the points that is gaining in quality in Morocco, it is necessary that the reforms of "soft" components accompany (Babounia A., El Imrani O., 2017).

Figure 4: Benchmarking the Average Ship waiting time



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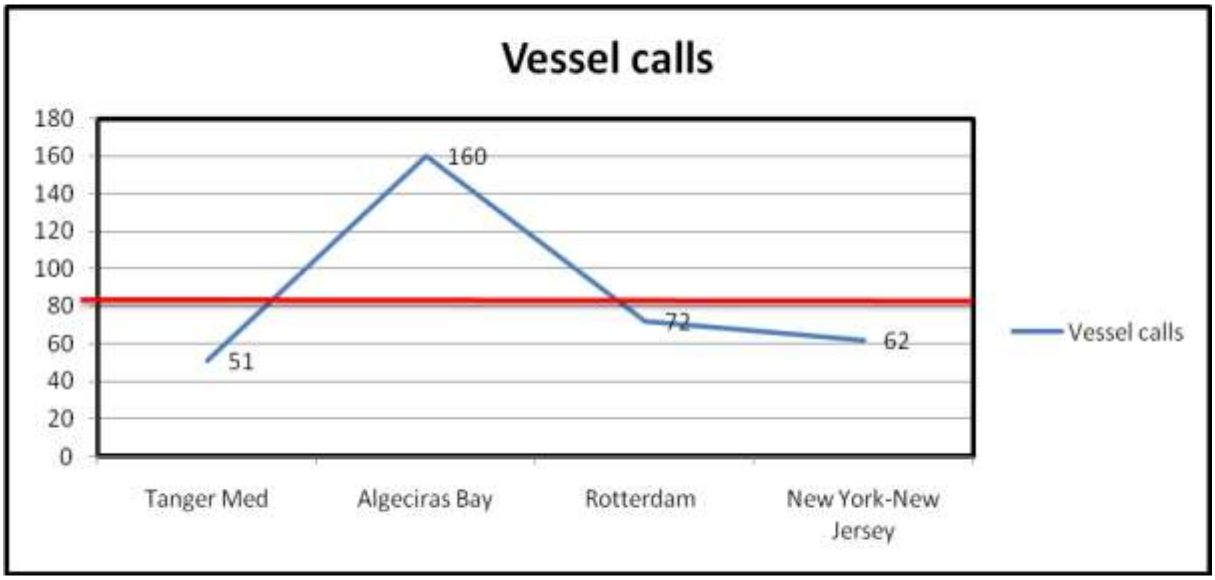
Average vessel call

The Figure 5 represents the average vessel calls by shippers and cargo carriers to the sample ports. The accepted benchmark value for the case port vessel calls was 86. Thus from the graph it can be seen that the Port of Algeciras Bay had the most number of vessel calls (160) and also shows validity to the results from the fig.3 and fig.2 that low turnaround time and low waiting time influences the number of vessel calls and carrier preferences (Ducruet et al., 2014; Slack & Comtoise, 2015).

Figure 5: Benchmarking the Average Vessel calls



Tonnage handled

The figure 6 shows the representation of the tonnage handled in various sectors of the terminal operations. Tanger Med port handled the most general cargo (111 m tonnes), while the dry bulk was most handled by NY-NJ Port (112.01 m tonnes) and Liquid Bulk was most handled by Port of Rotterdam (209.4 m tonnes). However, this tonnage cannot be suggested for the most efficiently handled ports, but mainly because of the hinterland connectivity and market demand. However, the export-import tonnage can be benchmarked for the most efficient operational port, beacuase lesser the time for ship turnaround more the tonnage for import and export loading and unloading. Port of Algeciras Bay had handled the most amounts of imports (39.5 m TEU) and exports (12.5 m TEU). Thus, it again shows higher the efficiency of port and ship operations, larger is the handling of export-import tonnage (Jafari et al., 2013).

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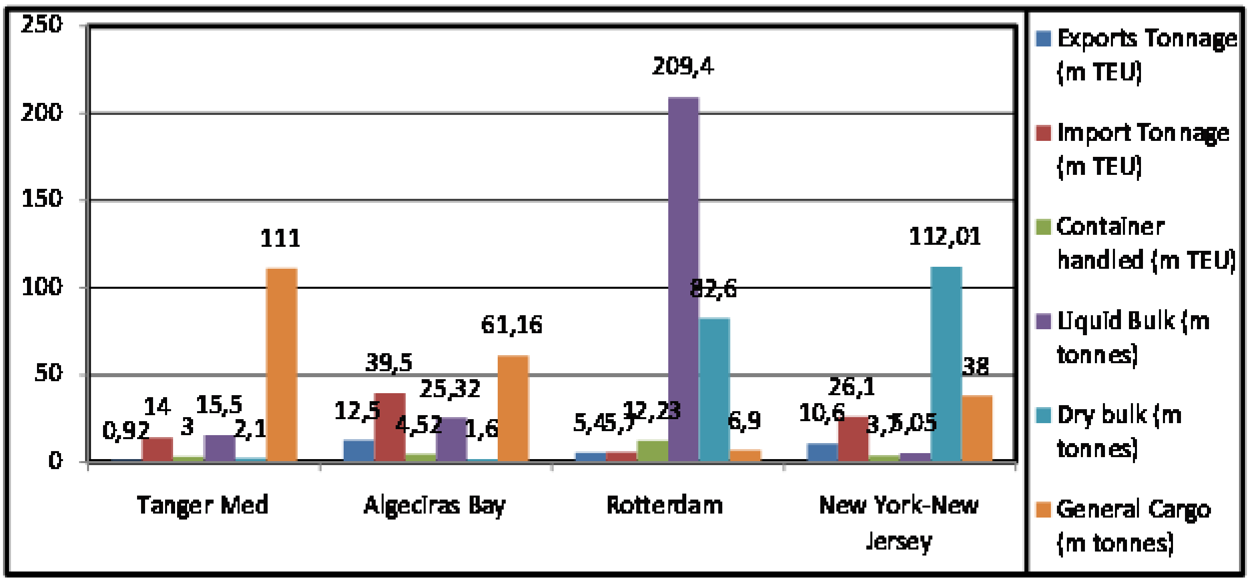
Figure 6: Graphical representation of tonnage handled



Port Efficiency Analysis

Data Envelopment Analysis (DEA) which shows either constant returns to scale (CRS) or variable returns to scale (VRS) on the basis of the equality of the input-output bundleand identical radial measures of technical efficiency (Proudlove, 2017). Using this tool the variables were put in MS Excel and DOS command DEA software and the results were run (Coelli, 2008). Below is the results table from the DEA tool of efficiency analysis of the benchmark values of the case ports. This tool was used specifically to benchmark the port's efficiency by input oriented measures for every input and output variable (Mohammadi et al., 2016). Radial models can be employed based on input or output discretionary or controllable input-oriented or output-oriented. This is an input oriented data envelopment analysis. Radial efficiency means "*that a proportional input reduction or a proportional output augmentation is the main concern in assessing the efficiency of the DMUs*"(Fukuyama, 2014; Pg. 1968).

Input oriented efficiency value against Average Ship Turnaround time

This is the CRS DEA result for input oriented efficiency benchmarking. Here the input variables were Berth Length, No. of Berths, Quay Length and No. of Quays and the output variable was Ship's turnaround time. From the Table 4 it can be seen that all the variables are technically efficient for Tanger Med Port and Algeciras Bay Port, as the efficiency score is equal to one. While for Rotterdam Port (0.035) and New York-New Jersey Port (0.800) there was inefficiency of the input-output ratio. This means that for Port of Rotterdam have to do additional improvement by decreasing inputs of 96.5% to become efficient (Port of Rotterdam, 2016b). Again for NY-NJ Port they have to increase output and decrease input by 20% to become efficient (JOC, 2017).

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Table 4: Table for Input oriented efficiency value against Average Ship Turnaround time

Input Oriented CRS DEA	
Case Ports or DMU	Input Oriented Efficiency Value
Tanger Med	1.000
Algeciras Bay	1.000
Rotterdam	0.035
New York-New Jersey (NYNJ)	0.800
Mean	0.709

Input Slacks against Average Ship turnaround time

Table 5 shows the results of the Input Slacks. In Data Envelopment Analysis, slacks show a unique value that can be explained on the basis of the excess input and minimal output even after proportional slack change(Coelli, 2008). However, the role of slacks is in the context of radial measures of efficiency. Tanger Med and Algeciras port had no slacks as they have an input efficiency value of 1. While Rotterdam and NYNJ showed slack values for the input variables berth length and quay length. The amount of the excess input that exists even after the proportional change for Rotterdam Port were found to be 1264.824 (berth length) and 23040.000 (Quay length), while for NYNJ Port 11620.560 (berth length) and 6453.913 (Quay length). Thus, the Rotterdam port can either lower their input or they can increase their output by 1264.824 (berth length) and 23040.000 (Quay length), while the same can be performed by New York-New Jersey Port by 11620.560 (berth length) and 6453.913 (Quay length). Slack values lead to another assessment result that is the reference set. Reference set or also known as peers are the set of efficient units from which an inefficient unit's inefficiency can be determined (Anderson, 2017). The peers or reference unit for Rotterdam and NYNJ Ports is Tanger Med Port. This also means that the low efficiency ports, Rotterdam and NYNJ do not have the best practice and their benchmark is Tanger Med port which has the best efficiency in case of Berth and Quay operations.

Table 5: Table for Input Slacks against Average Ship turnaround time

Summary of Input Slacks				
Case Ports or DMU	**Berth Length**	**No. of Berths**	**Quay Length**	**No. of Quays**
Tanger Med	0.000	0.000	0.000	0.000
Algeciras Bay	0.000	0.000	0.000	0.000
Rotterdam	1264.824	0.000	2775.652	0.017
New York-New Jersey (NYNJ)	11620.560	0.000	23040.000	2.000
Mean	3221.346	0.000	6453.913	0.504

Input oriented efficiency against Average Ship waiting time and Input Slacks

In this table 6 the input variables were again berth length, no. of berths, quay length and no. of quays, while the output variable was ship's waiting time. From the efficiency test it was seen that Tanger med and Algeciras ports had high efficiency with value of 1. However, Rotterdam (0.087) and NYNJ (0.952) had low efficiency of port performance. Thus, Rotterdam and NYNJ has to either decrease the input or increase the output by 91.3% and 5% respectively to become efficient (JOC, 2017; Port of Rotterdam, 2016b). Again, by the evaluation of input slacks, Rotterdam port can either lower their input or they can increase their output by 3162.061 (berth length) and 6939.130 (Quay length), while the same can be performed by New York-New Jersey Port by 13834.000 (berth length) and 8591.925 (Quay length) and 2.381 (No. of Quays). The peers or reference unit for Rotterdam and NYNJ Ports is Tanger Med Port.

Table 6: Table for Input oriented efficiency against Average Ship waiting time and Input Slacks

DMU	Input Oriented Efficiency Value	Summary of Input Slacks			
		Berth Length	No. of Berths	Quay Length	No. of Quays
Tanger Med	1.000	0.000	0.000	0.000	0.000
Algeciras Bay	1.000	0.000	0.000	0.000	0.000
Rotterdam	0.087	3162.061	0.000	6939.130	0.000
New York-New Jersey (NYNJ)	0.952	13834.000	0.000	8591.925	2.381
Mean	**0.760**	**4249.015**	**0.000**	**8591.925**	**0.606**

Input oriented efficiency against Average Vessel Calls and Input Slacks

The table 7 shows the efficiency for the input variables berth length, no. of berths, quay length and no. of quays against output variable Vessel calls. Evaluation for the efficiency of the ports showed that Tanger med, Algeciras and New York-New Jersey ports had high efficiency with value of 1. The output variable was the average of calls from every permanent and temporary cargo carriers. Rotterdam port although had more than a hundred carriers with port of calls but the average vessel calls on monthly basis was low, thus showing an inefficiency of 0.155. However, the inefficiency can be tackled by increasing their output by 85% (Port of Rotterdam, 2016b). By the evaluation of input slacks, Rotterdam port can either lower their input or they can increase their output by 1021.230 (berth length) and 4659.104 (Quay length). In this case the reference unit for the Rotterdam port is Algeciras port and NYNJ port.

Table 7: Table for Input oriented efficiency against Average Vessel Calls and Input Slacks

DMU	Input Oriented Efficiency Value	Summary of Input Slacks			
		Berth Length	No. of Berths	Quay Length	No. of Quays
Tanger Med	1.000	0.000	0.000	0.000	0.000
Algeciras Bay	1.000	0.000	0.000	0.000	0.000
Rotterdam	0.155	1021.230	0.000	4659.104	0.000
New York-New Jersey (NYNJ)	1.000	0.000	0.000	0.000	0.000
Mean	**0.789**	**255.307**	**0.000**	**1164.776**	**0.000**

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Input oriented efficiency against Import and Export Tonnage and Input slacks

Table 8 shows the results of efficiency test with input variables berth length andquay length, no. of berthsand no. of quays where the Import and Export Tonneage were the output variables. The berth and quay operations of a port influence the Import and export tonnage. Again, Rotterdam port was found to be the only inefficient port with 0.114 inefficiency value. However, the Rotterdam port can either decrease the input or increase the output by 89% to become efficient (Port of Rotterdam, 2016b). Evaluation of slacks showed that, Rotterdam port had an excess input even after the proportional change of 750.978 and 3426.146 for berth and quay length respectively. Thus, Rotterdam does not have the best practice and its benchmark ports are Algeciras and NYNJ port which has the best efficiency in case of Berth and Quay operations against export-import tonnage.

Table 8: Table for input efficiency against Import and Export Tonnage and Input slacks

DMU	Input Oriented Efficiency Value	Summary of Input Slacks			
		Berth Length	No. of Berths	Quay Length	No. of Quays
Tanger Med	1.000	0.000	0.000	0.000	0.000
Algeciras Bay	1.000	0.000	0.000	0.000	0.000
Rotterdam	0.114	750.978	0.000	3426.146	0.000
New York-New Jersey (NYNJ)	1.000	0.000	0.000	0.000	0.000
Mean	**0.779**	**187.744**	**0.000**	**856.537**	**0.000**

Input oriented efficiency against Container tonnage and input slacks

The input variables were the input variables berth length and quay length, no. of berths and no. of quays whereas the Container handled are the output variables.. Since the input variables contribute to part of port infrastructure and port infrastructure influences container handling. Only Tanger med had inefficiency of 0.105, but can improve it efficiency by increasing their output or lowering input by 89.5% (Imrani & Babounia, 2016). Its reference point or peer value is that of Port of Rotterdam and can benchmark its values for high efficiency. However, according to slacks value, Tanger med can decrease input or increase output by 0.157 (berth nos.) and 0.481 (quay length) to become efficient.

Table 9: Table for efficiency against Container tonnage and input slacks

DMU	Input Oriented Efficiency Value	Summary of Input Slacks			
		Berth Length	No. of Berths	Quay Length	No. of Quays
Tanger Med	0.105	0.000	0.157	0.481	0.000
Algeciras Bay	1.000	0.000	0.000	0.000	0.000
Rotterdam	1.000	0.000	0.000	0.000	0.000
New York-New Jersey (NYNJ)	1.000	0.000	0.000	0.000	0.000
Mean	**0.776**	**0.000**	**0.039**	**0.120**	**0.000**

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Input oriented efficiency against Container tonnage and input slacks

In this DEA evaluation the input variables were Channel depth, Cargo pier length, Anchorage depth and Oil terminal length against the output variable of Container handled. Since the input variables contribute to port infrastructure and port structure influences container throughput. From the table it can be seen that only Rotterdam port shows efficiency in case of container throughput, while Tanger med (0.187), Algeciras (0.297) and NYNJ (0.303) shows inefficiency. Thus, Tanger med, Algeciras and NYNJ can become efficient by either decreasing input or increasing output by 82%, 71% and 70% respectively (El Imrani & Babounia, 2016; JOC, 2017; Parola et al., 2016). Moreover, the slacks value shows that the ports Tanger med could either lower their input or they can increase their output by 0.368 (berth length), 1.128 (berth nos.) and 0.908 (quay nos.). Algeciras Bay can also improve their slacks by 0.256 (berth nos.), 1.819 (quay length) and 0.813 (quay nos.) and for New York-New Jersey port 0.454 (berth length), 1.392 (berth nos.) and 1.573 (quay nos.). The ports have their peer as Port of Rotterdam and benchmark it for the best practices towards port performance.

Table 10: Table for efficiency test against container tonnage and input slacks

DMU	Input Oriented Efficiency Value	Summary of Input Slacks			
		Channel Depth	Cargo Pier	Anchorage	Oil Terminal
Tanger Med	0.187	0.368	1.128	0.000	0.908
Algeciras Bay	0.297	0.000	0.256	1.819	0.813
Rotterdam	1.000	0.000	0.000	0.000	0.000
New York-New Jersey (NYNJ)	0.303	0.454	1.392	0.000	1.573
Mean	**0.446**	**0.205**	**0.694**	**0.455**	**0.823**

Input oriented efficiency against Container tonnage and input slacks

In this analysis the input variables were again Channel depth, Cargo pier length, Anchorage depth and Oil terminal length against the output variable of dry, oil and general cargo bulks handled by the port. From the table it can be seen that only Algeciras port has 0.866 of inefficiency and can become efficient by increasing output by 14% (Parola et al., 2016). Its reference port is Port of Rotterdam and can bench mark its values for best practices. Moreover, slacks value shows that Algeciras Bay could increase their output by 2.347 (channel), 9.151 (anchorage) and 2.524 (oil terminal) to become efficient.

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Table 11: Table for input efficiency against cargo bulks (General, dry and oil) and Input slacks

DMU	Input Oriented Efficiency Value	Summary of Input Slacks			
		Channel depth	Cargo Pier	Anchorage	Oil Terminal
Tanger Med	1.000	0.000	0.000	0.000	0.000
Algeciras Bay	0.866	2.347	0.000	9.151	2.524
Rotterdam	1.000	0.000	0.000	0.000	0.000
New York-New Jersey (NYNJ)	1.000	0.000	0.000	0.000	0.000
Mean	**0.966**	**0.587**	**0.000**	**2.288**	**0.631**

Input oriented efficiency against Export-import tonnage and input slacks

In this analysis the input variable were Channel depth, Cargo pier length, Anchorage depth and Oil terminal length against the output variable of Export and Import tonnage. Mooring is very important in ports and is done on the berths of the ports. This means that port infrastructure again influences the Export and Import tonnage.Tanger med and Rotterdam ports showed low efficiency of 0.419 and 0.683 respectively, but can increase their efficiency by increasing output by 59% and 32% respectively (El Imrani & Babounia, 2016; Port of Rotterdam, 2016b). However, slacks value shows that Tanger med can decrease their excess input or increase their minimal output by 0.627 (channel) and 0.862 (cargo pier), while Rotterdam by 0.670 (channel) and 0.564 (cargo pier) to increase efficiency. Both the ports can follow the peer or benchmark values of Algeciras port.

Table 12: Table for efficiency against Export-import tonnage and input slacks

DMU	Input Oriented Efficiency Value	Summary of Input Slacks			
		Channel depth	Cargo Pier	Anchorage	Oil Terminal
Tanger Med	0.419	0.627	0.862	0.000	0.000
Algeciras Bay	1.000	0.000	0.000	0.000	0.000
Rotterdam	0.683	0.670	0.564	0.000	0.000
New York-New Jersey (NYNJ)	1.000	0.000	0.000	0.000	0.000
Mean	**0.775**	**0.574**	**0.357**	**0.000**	**0.000**

Input oriented efficiency against vessel calls and input slacks

Here the output variable was Average vessel calls and contrasted against Port infrastructure because many time a vessel may or may not make port of call due to inefficient port infrastructure. Thus, on evaluation it was seen that Tanger med (0.411), Rotterdam (0.762) and NYNJ (0.656) were inefficient. However, the ports can either decrease the input or increase the output by 59%, 24% and 35% respectively for Tanger med, Rotterdam and NYNJ (Imrani & Babounia, 2016; JOC, 2017; Port of Rotterdam, 2016b). However, slacks

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values show that Tanger med can decrease their excess input or increase their minimal output by 2.550 (Channel), 3.506 (Cargo Pier) and 2.550 (Oil Terminal); for Rotterdam, 2.457 (Channel), 1.445 (Cargo Pier) and 0.780 (Oil Terminal) and for New York-New Jersey, 3.100 (Channel), 4.262 (Cargo Pier) and 4.084 (Oil Terminal). The peer or benchmark value for best practice is Algeciras Bay Port.

Table 13: Table for efficiency against vessel calls and input slacks

DMU	Input Oriented Efficiency Value	Summary of Input Slacks			
		Channel depth	Cargo Pier	Anchorage	Oil Terminal
Tanger Med	0.411	2.550	3.506	0.000	2.550
Algeciras Bay	1.000	0.000	0.000	0.000	0.000
Rotterdam	0.762	2.457	1.445	0.000	0.780
New York-New Jersey (NYNJ)	0.656	3.100	4.262	0.000	4.084
Mean	**0.707**	**2.027**	**2.303**	**0.000**	**1.854**

Benchmarking Ports

Based on the data envelopment analysis (DEA) for benchmarking and efficiency of the case ports a rank has been suggested on the basis of the most input oriented efficient Ports.

Table 14: Ranks on the basis of the No. of Input Oriented Efficiency counts

Rank	Port	No. of Input Oriented Efficiency counts
1	Port of Algeciras Bay, Spain	7
2	Port of Tanger Med, Morocco Port of New York-New Jersey, USA	5
3	Port of Rotterdam	3

Further, the benchmarked values for each of the ports individually are presented in the table below.

Table 15: Table for characterizing the benchmarked variables for very port and their reference efficient port

Ports	Benchmarked Variables		Reference Port
	Input	Output	
Port of Tanger Med	Quay and Berth Infrastructure	Container Tonnage	Rotterdam
	Overall Port Infrastructure (Channel depth, Cargo pier length, Anchorage depth and Oil terminal length)	Container Tonnage	Rotterdam
		Export-Import Tonnage	Algeciras Bay
		Vessel calls	Algeciras Bay

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Port of Algeciras Bay	Overall Port Infrastructure (Channel depth, Cargo pier length, Anchorage depth and Oil terminal length)	Bulk Tonnage	Rotterdam
		Container Tonnage	Rotterdam
Port of Rotterdam	Quay and Berth Infrastructure	Ship Turnaround time	Tanger med
		Ship waiting time	Tanger med
		Vessel calls	Algeciras and NYNJ
		Import and Export Tonnage	Algeciras and NYNJ
	Overall Port Infrastructure (Channel depth, Cargo pier length, Anchorage depth and Oil terminal length)	Export-Import Tonnage	Algeciras Bay
		Vessel calls	Algeciras Bay
Port of New York-New Jersey	Quay and Berth Infrastructure	Ship Turnaround time	Tanger med
		Ship waiting time	Tanger med
	Overall Port Infrastructure (Channel depth, Cargo pier length, Anchorage depth and Oil terminal length)	Vessel calls	Algeciras Bay
		Container Tonnage	Rotterdam

From the above table 15, it can be interpreted that for Tanger med port, their inefficiency of port lies in infrastructure against Container tonnage, Vessel calls and Import-Export tonnage, but to improve efficiency can follow the benchmark variables of Port Rotterdam and Algeciras Bay respectively. Similarly, for New York-New Jersey port, their inefficiency of port lies in infrastructure against Ship turnaround time, Ship waiting time, vessel calls and container tonnage, but can improve by benchmarking the input variables of Tanger med, Algeciras and Rotterdam respectively.

DISCUSSIONS AND CONCLUSIONS

Port efficiency is the measure to check how efficient is the port's operation and a ratio between output and input variables of the ports performance. From the analysis of efficiency analysis and benchmarking variables, it can be said that even if a port may invest in excess to increase the performance and competitiveness with other ports of the country or the world they may not equally be efficiently working. The case can be compared with Port of Rotterdam that, even if from the current data collected showed manually that Port of Rotterdam had the best performance compared to the other three ports but is not equally efficient as the lowest performing port, Port of Tanger med. This shows relevance with the reports from Port of Rotterdam where they mention a low port throughput. The ports of NYNJ and Algeciras Bay too showed that even with low input for high performance, the ports were working efficiently. From the analysis it can be said that the most important factors that influence the port efficiency are port infrastructure and terminal operations. Other than these factors, dwell time, crane moves per hour and time spent at anchorage, too contribute to port efficiency. Thus, the benchmarked variables found are; Quay and Berth

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Infrastructure, Port Operation and Port infrastructure. The benchmarking values of the Rotterdam port is container and bulk tonnage which also means that it can follow or refer Algeciras and Tanger med port to achieve achiement.. Algeciras port performance model benchmarked for Vessel call and Export-Import Tonnage and can be followed by Rotterdam, Tanger med and New York-New Jersey port. Tanger med port performance model benchmarked for ship turnaround time and waiting time can be followed by Rotterdam and New York-New Jersey port.

It is recommended that the case ports with inefficient values for respective input and output variables can follow the reference benchmarked performance models of the case ports. Tanger med port can follow the performance model of Rotterdam and Algeciras port for Container, Bulk tonnage, Vessel call and Export-Import Tonnage. Likewise the other ports should follow the benchmarked performance models for efficiency elevation.

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