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THE DEVELOPMENT OF A PORT PERFORMANCE MEASUREMENT SYSTEM USING TIME, REVENUE AND FLEXIBILITY MEASURES

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ABSTRACT

Ports are considered as a necessary element for facilitating seaborne traffic. A wide range of performance measurement systems and frameworks have been developed for this purpose using different techniques. This helps to monitor the performance of operations and terminals in a port through providing a port with indicators that will assist in assessing port productivity, and management of complicated operations. Findings considered that current systems are limited as they focus primarily on measuring containerised cargo and lack the focus of measuring overall port performance. This paper aims to contribute to the development of knowledge and develop a port performance measurement system at Damietta port, Egypt which considers not only containerised cargo but also other types of cargo namely: general cargo, dry bulk and liquid bulk. Three measures were used for this purpose, namely time, revenue and flexibility measures. Multiple regression analysis has been applied as a quantitative approach for the time based performance measures. Revenue measures help to add visibility to revenue created by the port. Flexibility measures help the port manager to deal with uncertainty in demand. Data has been collected form structured interviews, port reports and dedicated workshops for five years from 2004 to 2008, on monthly basis.

KEYWORDS: Port Performance, Operations Time, Regression Analysis

INTRODUCTION

Managers and authorities at ports have increasingly been under pressure to improve port performance by ensuring that the port provides services on an internationally competitive basis. The diversity of port managers' responsibilities, the complex market structure of port industry, and managing port facilities require using a reliable management and measurement tool (Simoes and Marques, 2010). Measurement systems are required to assess the current cost, productivity and service levels at ports and to identify deficiencies within these ports. Hence, many studies were carried out in port economics, port policy, port management, port terminals and port planning for evaluating port performance (Pallis *et al*, 2011). Analytical methods such as queuing models, stochastic frontier, data envelopment analysis, and simulation models have been the most common measurement approaches used in measuring port performance. Performance measurement becomes an important factor for effective planning and decision making (Chan, 2003; Chan *et al*, 2003).

Measurement systems help in evaluating how existing capacity and port performance meet the requirements of the shippers and ship owners in terms of the waiting time of the ship, and how it can meet the consignees' expectations in terms of the dwelling time of cargo. A port has many terminals and normally handles more than one type of cargo; dry bulk, liquid bulk and general cargo. A focus on measuring one type of cargo does not reflect overall port performance. Hence, the evolution of measurement systems over time remain a considerable gap in performance measurement research (Kennerley and Neely, 2002). A systemic approach to port performance measurement is required (Bichou and Gray, 2004).

This paper is focused on developing a performance measurement system and is structured in the following way: Section 2 provides a comprehensive review of current approaches to port performance measurement systems. Section 3 discusses relevant aspects of the methodology and methods used in developing the measurement system. Section 4 examines the effectiveness of the current measurement approach applied in Damietta port. Section 5 develops a measurement system to be used in Damietta port, named Damietta Port Performance Measurement System (DAPEMS). Section 6 gives policy implications of the findings, concluding limitations and highlights potential areas for future works.

SECTION 2: SUPPLY CHAIN PERFORMANCE MEASUREMENT AND PORT STUDIES

This section reviews current performance measurement systems that are used in ports and evaluates their effectiveness. The measurement of a port's performance has been approached by researches in many different ways and using a range of key performance indicators (KPIs) including financial indicators such as income statement, operational indicators such as ship turn-around time, macro indicators, micro indicators, productivity indicators, output indicators, service indicators and utilisation indicators, with regard to technical efficiency, cost efficiency and productivity. Furthermore, port performance can be measured using a KPI of linkage. It refers to a linkage between port hinterland and the inland transport network (EL-Sakty, 2003).

Port Performance Measurement Approaches

A diversity of systems and frameworks has been developed for assessing the performance of ports. Bichou (2007) argued that current measurement approaches are incompatible with the port industry.

Bichou claimed that few approaches have linked and integrated operations, design and strategy with port functions. Table 1 summarises these common approaches that have been developed for assessing ports' performances.

Table 1: Performance Measurement Approaches Applied in Ports

Author	Applied Model	Focus	Limitations
Tongzon (1995)	Throughput model	Containerised ports	Average inputs
Notteboom et al (2000)	SFA	Port efficiency	A single year of data
Tahar and Hussain (2000)	Simulation	Crane productivity	Missing key factors
Tongzon (2001)	DEA	Controllable inputs	Poor data availability
Estache et al (2001)	SFA	Containerised ports	Limited inputs
Valentine and Gray (2001)	DEA	Containerised ports	Not clear in practice
Itoh (2002)	DEA	Container ports	DMU system focus
Wang et al (2003)	DEA-CCR, DEA-BCC, FDH	Throughputs	Unavailable data
Cullinane and Song (2003)	SFA	Productive efficiency	Privatised ownership focus

Park and De (2004)	BCC, CCR	Throughputs	One year of data
Tongzon and Heng (2005)	SFA, Liner Regressions	TEU's measurement	Simple model
Jaffar et al (2005)	TEU	Containerised ports	Irrelevant parameter
Roh et al (2006)	SADT	Efficiency	Port users focus
Bichou (2007)	Panel Survey	Benchmarking	
Barros and Managi (2008)	DEA	Port efficiency	Missing key variables
Gonzalez and Trujillo (2009)	SFA and DEA	Efficiency	No clear methodology
Sharma and Yu (2010)	Decision-tree Approach	Terminal attractiveness	Container terminal
Zouari and Khayech (2011)	‘Cost-Quality-Delay’ method	Logistical port performance	Commercial and operational focus

One of the main research studies undertaken in this field was by Tongzon (1995) in which he established a model of port performance and efficiency. The study aimed firstly to identify the factors that influence port performance. Then, it turned to quantify the relative contribution of these factors to the overall port performance. The model examined only containerised cargoes across a selected sample of 30 container ports. The study concluded that the aspect of terminal operation constituted the largest component of the total ship turn-around time. Valentine and Gray (2001) applied the DEA model for 31 container ports. They examined the relationship between certain types of port properties, such as waiting time, ship turn-around time, and organisational structures, with efficiency.

They concluded that such relationships lead to higher efficiency and in turn these relationships affect port performance. Cullinane and Song (2003) applied Stochastic Frontier Analysis (SFA) model to assess the improvement in productive efficiency for those Korean ports which had been privatised. The study focused on container terminals, using cross-sectional data and panel data. Ng (2005) focused on scheduling problem in container ports. He considered a terminal turn-around time as a key performance measure in terms of how long a vessel stays in a terminal. Simulation has been used as a method in measuring port performance. Many simulation models of port operations, especially container port operations, have been developed (Tahar and Hussain, 2000; Bielli *et al*, 2006). Simulation models have been used for different purposes such as: the planning of future berth requirements of a third-world port; proposing a method that uses buffer space to reduce container loading times and optimise equipment utilisation; studying the impact of work crew schedules on container port productivity; and as a supportive tool for evaluating and improving port activities. Goodchild and Daganzo (2007) examined the impacts of crane double cycling on turn-around time. They argued that using double cycling will lead to improved port throughput, berth productivity and vessel productivity.

Gonzalez and Trujillo (2009) grouped measurement approaches for port efficiency into three groups. The first group comprises the partial productivity indicators. The second group includes engineering approaches such as queuing theories. While, the third group involves the technical frontier techniques. Sharma and Yu (2010) claimed that traditional DEA approach was not helpful in ranking Decision Making Units (DMUs) based on their relative degrees of efficiency and inefficiency, nor identified these variables that have great impacts on the efficiency.

Hence, they applied the decision tree approach based-DEA on 70 container terminals. They concluded that terminals with high attractiveness scores have less treats and therefore highly attractive, and vice versa. Each port applies different KPIs and analyses various measures. The following reasons explain why current port measurement approaches are inconsistent and unsatisfactory. Firstly, current measures and KPIs focus on measuring productivity issues rather than measuring performance such as port infrastructure productivity (Turner *et al*, 2004). Secondly, current measurement systems focus on measuring productivity and performance for a certain terminal or terminals rather than for the whole port (Valentine and Gray, 2001; Ng, 2005; Cullinane *et al*, 2002; 2004; Pallis *et al*, 2011). Thirdly, current measurement systems lack a strategic focus. The focus is often towards improving terminal productivity rather than improving port performance. Fourthly, cost is the primary issue in most systems. Most measurement systems rely heavily on financial principles (Tangen, 2004) and most port studies developed frontier cost approaches, and considered port efficiency as a determinant of maritime transport cost (Sanchez *et al*, 2003). Fifthly, most measurement systems are not applicable in practice, or managers have not indicated how to apply these in reality (Bichou and Gray, 2004).

Sixthly, measuring the efficiency side is the main focus in the current systems (Brooks and Cullinane, 2007; Pallis *et al*, 2011). Seventhly, measuring containerised cargoes, container port and container terminals are the objectives of most current systems (Pallis *et al*, 2011). Eighthly, different techniques such as DEA and SFA have been used in terminal studies in recent years. Challenges remain to use other quantitative approaches to develop a more effective performance measurement system.

Ninthly, some key performance variables have been ignored that have great influence on port performance such as standing time and clearance time. Finally, most measurement systems focused on assessing historical performance rather than future performance, and these systems were designed for external reporting rather than managing the business enterprises (Bourne *et al*, 2000).

SECTION 3: METHODOLOGY

This paper aims to develop a port performance measurement system and it has set the following research questions for this purpose: what is the measurement system that is currently applied in measuring Damietta port's performance?, what is the effectiveness of the current measurement system in Damietta port?, how can the current performance measurement system be developed to measure overall port performance?, what are the relative and relevant variables that influence a port performance and have not been considered in current models? and what is the significance of the relationship between these variables?

The deductive methodology has been set to answer the previous questions. Quantitative approach is traditionally applied in measuring port performance (Marlow and Casaca, 2003). It enabled an involvement in the port working environment, which enhanced data collection processes, sampling size, data type, data preparation, timing, data analysis and level of data security. Thereafter, interviews with the port managers and directors were conducted thirteen times to verify the accuracy and reliability of data and to identify their needs in terms of performance measurement system. The strategy for carrying out this research is a case study strategy as it considers the use of data and involves empirical investigation at Damietta port.

This strategy helps to generate answers to ‘how’, and ‘what’ questions through providing a rich understanding of the real environment (Saunders *et al*, 2003). Damietta port is used as a case study as data was readily available to comprehend how variables can affect port performance. Also, a case-study strategy helps to use various data collection methods that enable to explain the existing theory. Yin (2003) claimed that this type of case study is based on factor theory where the relationship between independent and dependent variables can be explained and analysed using statistical technique. Hence, the Ordinary Least Square (OLS) regression is a fitting procedure used for data analysis as statistical technique. Developing DAPEMS requires a specific process. Selecting the right measures for proper system design firstly requires the strategic objectives to be defined (Keegan *et al*, 1989). A measurement system should be strategically oriented and use acceptable parameters rather than focusing on the actual output of the process (Maskell, 1989). After considering the strategic objectives of the port, the next step is to design a system through selecting these measures that shape a system. Measures should include financial and non-financial measures (Maskell, 1989). Neely *et al* (2000) recommended that measures should be simple, easy to use and provide fast feedback.

Performance measures are a part of a system that can be used to quantify actions or a process (Braz *et al*, 2011). Current measures that influence Damietta port performance are also considered as a third step. Braz *et al* (2011) argued that existing measures are rarely deleted. New measures should be selected in priority related to the strategic objectives as discussed earlier, and through involving the port managers to determine what their needs are (Neely *et al*, 2000). The fourth step will examine the relationship between these variables and port performance.

In the fifth step, developing a more effective measurement system has taken place using three measurement categories: time, revenue and flexibility.

SECTION 4: CURRENT PERFORMANCE MEASUREMENT OF OPERATIONS AT DAMIETTA PORT

This sections analysis the current performance measurement approach applied in the port and to examine its effectiveness. Different research methods have been applied for this purpose; including interviews, port records, governmental publications, port visits, observation, internet and literature review. The port was constructed in the early 1980s and it began its operation on July 1987 for the purpose of improving the flow of trade-traffic across the Mediterranean coast of Egypt. Damietta Port is located in Northern Egypt and it is about 8.5 km west of the Damiet**t**a branch of River Nile.

It has a strategic location near the Suez Canal and other Mediterranean hub ports, particularly East Port Said port (Suez Canal terminal). It has five terminals and the port installations extend access an area of 11.8 sq. Km. It is considered as a multi-purpose port and it is linked with different modes of transport and it has 18 berths. The Damietta Port Authority (DPA) takes into consideration that the number of ships calling the port is the key prerequisite to measure the port performance. The port authority believes that determining the number of ships calling at the port helps understand the streamline flow of all types of cargoes. DPA records the number of calling ships per month as a key performance indicator. Then, it, as in other public Egyptian ports, compares total number of ships and total volumes handled in the port on monthly and yearly basis to show if there is an increase or decrease in total number of calling ships. The number of calling ships at Damietta port has increased significantly since its opening in 1987. The port received 3259 ships in 2010. A focus is mainly on container terminals and containerised cargo.

Little attention has been given toward other types of cargo by the port managers in the process of evaluating the performance. As discussed in the literature, most current performance measures focus on containerisation rather than generalised cargoes.

It is argued that measuring Damietta port performance in terms of the total number of calling ships, either container or general cargo ships, is inadequate and it does not reflect port performance. Interviews showed that the port's manager's uses only berth occupancy in measuring performance, with no regards to other records. Other measures are used by DPA in assessing the port performance, including total volumes handled. It is obvious that Damietta port managers focus on productivity measures more than performance measures in assessing their port performance. It can be concluded that no measurement system has been applied to assess the port performance.

SECTION 5: DEVELOPING DAPEMS USING TIME, REVENUE AND FLEXIBILITY MEASURES

Damietta port managers work in a complicated and dynamic environment where every ship calling at the port requires different preparations and where every operation requires the use of different facilities. Hence, port performance is determined by a variety of predictor variables. The growing complexity of operations in ports and the use of inadequate predictor variables represent a strong argument towards developing a more effective performance measurement system. This section discusses how DAPEMS can be developed using time, revenue and flexibility measures.

Developing DAPEMS Using Time Measures

The following determinants are considered relevant when building DAPEMS:

- **A Ship Turn-Around Time**

The total time a ship stays in port is a key performance indicator and clearly affects port performance and freight rates. Any port is not a holding point, and the challenge is to move cargo on board or to deliver it to cargo owners in the shortest time.

The authors argue that the time a ship spends in port or at berth is important to be considered as it carries cargoes and it cannot be discharged until a ship is at berth and starting discharging operations. The longer a ship stays in the port, the greater the cost for ship owners, shippers and port clients (EL-Sakty *et al*, 2009).

- **Grouping Port Operations**

Port operations have been grouped by the authors into five groups. Ship-side activities involve loading and discharging rates per day, berth occupancy, waiting time at berth and number of calls. Land-side activities involve distance between berths and warehouses or port gates and in-port transportation.

Equipment operation involves the amount of available equipment, their capacities and efficiency. Storage operations involve types and number of warehouses and their storage capacities. Clearance activities refer to the required time to accomplish the required documentation and clearance.

- **Consideration of Other Types of Cargoes**

There are different classifications of cargoes according to the handling method, principles of stowage, principles of taint and ventilation and weight. Types of cargoes according to handling method will be considered, because handling activity is most important in ports. Damietta port handles four types of cargoes, namely; general cargo, dry bulk, liquid bulk, and containers.

Developing steps start with defining the structure through determining the assumptions of the proposed system (Neely, 1995). The system's assumptions help in understanding what performance measures should be used, what they are used for, and what benefit they provide. In time measures, regression analysis has been applied as a method for explanation of phenomena and prediction of Damietta port performance. At the beginning, it is important to determine the response and the predictor variables. Response variables were derived from the port strategy. It is important to determine a response that connects the port's operations with its strategy (Shepherd and Gunter, 2006; Neely, 1995). Damietta port strategy focuses on optimising the required operations that influence how long cargo stays in the port. 'The focus is always towards reducing the total time cargo remains in the port', the port director said. Marlow and Casaca (2003) argued that a port needs to be lean through moving cargo quickly and smoothly in alignment with port demand. Reducing the total time cargo remains in the port will improve port performance and increase the port clients' satisfaction. This helps the port to have a competitive advantage to compete with other ports in the Mediterranean basin.

Hence, the total time cargo remains in the port will be used as an indicator for determining whether port performance is improving or deteriorating. For determining the predictor variables, two questions need to be addressed, as they help identify the rest of the assumptions of DAPEMS: what are the predictor variables that influence the total time cargo remains in port? and how are those variables interrelated, and how can they be calculated?

For the first question, the answer is that the total time cargo remains in port is influenced by the total time a ship spends in the port (TS) and clearance time (CT). TS refers to the total time between a ship's arrival in a port to its departure. It includes ship turn-around time. For TS, it is corroborated berthing time (BT), un-berthing time (UBT), standing time (SD) and operation time (OT), as in the equation (1):

$$TS = BT + UBT + 2*SD + OT \quad (1)$$

DPA has provided data for BT, UBT, and SD variables. The problem existed in getting data about OT. OT refers to total time required for loading and discharging cargo at berth. Currently, there is no formal recording of operation time in Damietta port. Hence, regression analysis was performed to calculate OT.

For the second question, the authors reasserted as that OT is part of TS, and that TS and CT influence, in turn, the total time cargo remains in ports. This assumption explains how variables are interrelated. It helps also to understand the structure of DAPEMS. It can be concluded the remaining assumptions incorporated are as follows:

- Reducing the total time cargo stays in the port will improve port performance.
- Reducing TS and CT should minimise the total time cargo remains in ports.
- OT, BT, UBT, and SD are parts of TS.
- There are seven key predictors that influence OT. Two variables have constant values according to the available data in Damietta port. These values have not been considered in regression analysis: equipment and in-port transportation.
- Ordinary Least Square (OLS) regression analysis has been applied in calculating OT.
- It is assumed that the port does not operate its facilities at 100 % utilisation rates.
- The Egyptian ministry of transport has set constant values for all fees, dues and associated costs. These values are applied in all Egyptian ports.

For TS calculation, reducing the total time a ship stays in the port (TS) should reduce the total time cargo remains in the port. When a ship stays in a waiting area or anchorage area and it is loaded with cargo, it is important to consider this time as cargo is being held on board and it cannot be discharged until a ship is at berth. Hence, berthing and un-berthing times and standing time should be considered. BT, UBT and SD data have been gathered for four types of cargoes, including general cargo, dry bulk, liquid bulk and containers.

For OT calculation, regression analysis has been applied to examine the relationship and cause and effects between OT and key performance variables. Table 2 shows that there are seven important variables influencing OT.

Table 2: Predictor Variables Influencing OT

Symbol Used	Predictor Variable (s)	Classification
OT	Operations time	Dependent
Constant value	Equipment	Independent
Constant value	In-port Transportation	Independent
NCS	of calls .No	Independent
TTH	Total tonnes handled	Independent
BO	Berth occupancy	Independent
LDR	discharging rates/Loading	Independent
ST	Storage	Independent

The question is why do these variables influence OT? and, in turn, why do these variables influence port performance? Firstly, these variables influence OT as they represent key operations required to complete the required loading and discharging. Secondly, they have a direct impact on the total time cargo stay in port. Thirdly, these variables influence the setting of freight rates and operation costs. Many simple and multiple regression models have been performed separately to calculate OT. The aim is to find the best fitting models.

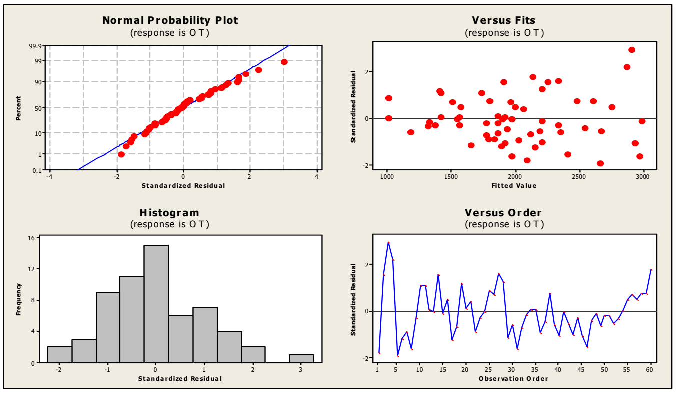
In general cargo, no significant improvement was observed when LDR was added to the model. The reason is the ST predictor plays an important role in the general cargo at Damietta port. A sufficient number of storage areas and the capability of the equipment serve to increase the handling rate (LDR predictor). Also, the rate of loading and discharging differs from one type of general cargo to another, which cannot be considered as a leading factor for OT_{gen}.

In addition, LDR has no significant effects because most general cargo discharged at Damietta port is a measurement cargo (light cargo). For TTH the best fitting model has excluded TTH because there is a strong relationship between NCS and TTH, as it accounted for 89%. This is called multicollinearity in the regressors, which leads to unreliable estimates of the regression coefficients (Draper and Smith, 1998). Also, VIF test shows that TTH's VIF equals 5, which leads to poor estimation.

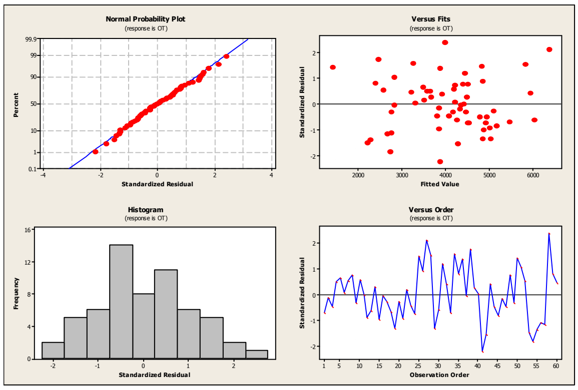
In dry bulk cargo, it was found that BO and LDR have no significant relationship with OT_{dr}. BO predictor is not significant because dry bulk cargo is subject to inspections before loading and discharging according to Egyptian law. The first inspection is conducted after the ship's berthing. Ships will wait about 24 hours for the result of the first inspection. The second inspection is carried out two days later during discharging. For the LDR predictor, it has no significant influence on OT_{dr} because bulk ships are usually discharging using portable evacuators which have a very high productivity rate. Thus, the handling rate is very high and dry bulk ships are required to discharge again directly into trucks, as Damietta port does not have a grain silo to store the grain cargo. VIF test shows that there is no perfect multicollieanarity between predictors.

In liquid bulk, it was difficult to select the best fitting model as there were many goodness-of-fit models. The best model above has excluded BO predictor, mainly, to avoid multicollinearity. Introducing the BO predictor, with multicollinearity, leads to two problems. The first problem is that the individual P value becomes misleading as the P value is high, even though the variable is important. The second problem is that the confidence intervals on the regression coefficient become very wide. The BO predictor has a strong relationship with NCS and ST. VIF test shows that BO's VIF equals 11.7 indicating high multicollieanarity.

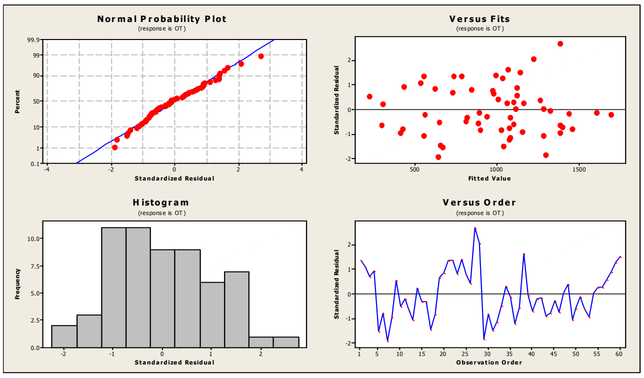
Also, excluding BO was because most liquid cargo necessitates safety measurements prior to, during and after loading. Ships are subject to safety inspection by loading station management, which take a long time. Also, some measurements should be performed before starting the loading operation; such as checking the level of liquid in tanks and calculation of liquid temperature and density. After completion of loading operations, ships are again subject to measurement and cargo calculation before they are ready to sail. In addition, some liquid bulk ships require a cooling operation to cool down the tanks, cargo pipes and valves in order to receive cold cargo. This means that ships occupy the only berth that the liquid bulk terminal has, with no operations being actually performed. Hence, the BO predictor will not contribute significantly to the model. LDR predictor is also not statistically significant, as p-value = 0.102. This is because loading starts at a slower rate, which increases after ensuring that all pipes and valves are setup in the correct manner. Also, before the end of the loading operation, the station will slow down the loading rate again to avoid spillage. In containers, it was obvious that the selected model has excluded TTH. The reason is the transit shipment. These containers stay in the port in contrast to those containers delivered into the country, which are known as domestic containers. Thus, not all containers require the same OT_{con} . This may explain why the influence of TTH is low. Thirdly, handling containers depends on a range of factors; such as empty containers and full-loaded containers where empty containers can be moved and stacked fast. In Damietta port, empty containers constitute about 30 %of total containers handled at the container yard per year. Fourthly, VIF test shows that including TTH variable will lead to poor estimation. VIF equals 5 with milled multicollieanarity in case of including TTH.



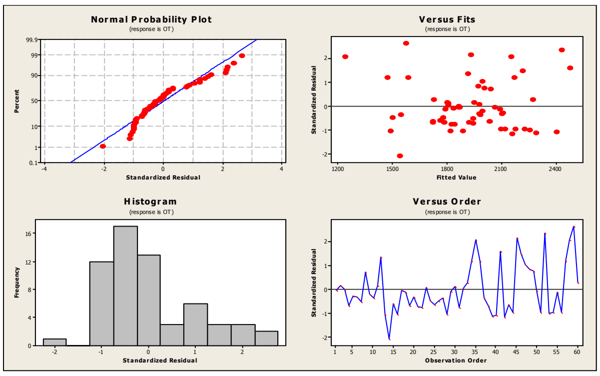
Residual Plots for OT in General Cargo



Residual Plots for OT in Dry Bulk



Residual Plots for OT in Liquid Bulk



Residual Plots for OT in Containers

Figure 1: Residual and Probability Plots for All Types of Cargoes at Damietta Port

From performing tens of residual plots and probability plots, Figure 1: displays, for example, that a normal probability plot points generally form a straight line, which means that the residuals are normally distributed. Residuals versus fits showed a random pattern of residuals on both sides of 0. It indicates that there is not a predominance of positive or negative residuals, as residuals are randomly distributed about zero and less concentrated.

It can be accepted that the relationship is linear between variables, because the residuals do not appear to form a curve. Histogram examined the variation and shape characteristics of the data using a histogram of residuals. The histogram showed that normally distributed data are relatively little skewness. Residuals versus order indicated that non-random error. A positive correlation is indicated by a clustering of residuals with the same sign. The versus order showed that there is no correlation between random errors, which means that they are independent of each other. According to regression theory, it means that the regression follows the assumption of OLS estimation.

For CT calculation, DPA has a record for CT for all types of cargo handled in the port. CT data have been gathered, organised and entered to MINITAB software. No calculations was carried out to calculate CT. Available data have been approved and verified by the MOT and custom association to prove the data reliability.

Developing DAPEMS Using Revenue Measures

Few studies calculate port demand and revenue function (Talley, 2007). The focus was on port revenue generated from the transfer of cargo from and to ships. The focus was on two sources of revenues: ship revenue and cargo revenue.

Ship revenue was determined by port dues, while cargo revenue was determined by cargo handling operation time and volumes. Kim and Sachish (1986) to calculate port revenues, and where ORt is the operating revenue for year t have applied equation 2.

$$\text{Marginal Revenue} = [(OR^{t}-OR^{t-1})-(OR^{t}/y^{t})(y^{t}-y^{t-1})]/(CON^{t}-CON^{t1}) \quad (2)$$

Le-Griffin and Murphy (2006) discussed the possibility for container terminal operators to increase their revenue through increasing container handling productivity or increasing working time at berths. These procedures will minimise the time containers spend in port and in turn it will attract more ships to call. Talley (2007) related port profit with port throughput. He compared a port's actual throughput to its optimum throughput to determine whether a port’s performance is improving or not, and in turn, to determine whether port revenue increasing or decreasing over time. Tongzon (2009) explained that port charges vary according to port nature and functions, which in turn affects port revenue. He discussed two types of revenue sources, including ship-based types and cargo-based types. Pallis and De Langen (2010) discussed the results of financial crises on port revenue and profit.

They claimed that a decrease in volume and traffic leads to a decrease in revenue. Also, lower dues, discounts granted to ship operators, lower tariffs for larger ships, lower handling fees for large quantities and discounts granted for new traffic in some location. Hence, they suggested encouraging investment in port ownership, leasing and construction. Increasing the total time that cargo stays in Damietta port or in any other ports means extra tariffs should be paid by the port clients. Tariffs may cover grounding rent, storage costs and handling fees.

These tariffs are considered as charges for the port clients, and at the same time, they are revenue for the port itself. This means that increasing the time that cargo remains in the port will lead to increased revenue to the port. The port revenues can be maximised if the port clients pay more tariffs, and this can take place in one of the following cases:

- If cargo stays longer time in the port, which requires grounding rent and rent of port facilities;
- If volumes of handled tonnes increase; or
- If OT increases as facilities and rented equipment are used for longer periods of time.

These cases above refer to more income to the port and more expense to the port users. No doubt, the second case is more preferable. However, increasing volumes may lead to port congestion and consequently for cargo to remain longer. It is complicated to make a balance between these cases above. Equation 3 can be used to calculate the port revenue from operation time OT and it can make a balance between the above cases:

$$\text{Port revenue} = \alpha * \text{no. of tonnes handled} * \text{elapsed time} \quad (3)$$

(Where α refers to a constant tariff)

- Revenues generated from OT

In Egypt, the Ministry of Transport sets fixed tariffs for all operations in all Egyptian ports that cover loading and discharging costs (OT), total cost paid by ships at berths due to how long the spend in the port (TS), clearance (CT), and storage costs. Decrees number 393, 394, 395 and 520/2003 illustrate that tariffs are valid from 2003 until now and applied to all types of ships, Egyptian and foreign ships. These tariffs are constant, but they vary with two parameters: how many tonnes handled in Damietta port, and how long cargos spend in the port.

Equation 4 was developed to calculate the port revenue from OT:

$$\text{Port revenues from OT} = \alpha * \text{total tonnes handled} * \text{OT} \quad (4)$$

Where α refers to tariffs that port clients should pay. The value α differs from one type of cargo to another. Also, α value for TS is different from α value for OT operation, simply, because each operation has different elements and each operation uses different port facilities. For the OT, α value includes loading and discharging fees per tonne per hour. For TS, α value comprises port and light fees, towage (in and out) fees, Pilotage (sea and port pilot) fees, moor and unmoor fees and port state fees.

For general cargo, dry bulk and liquid bulk, the α element of the fees includes loading and discharging from ship to berth and vice versa. While for containers, there is more than one element for handling tariff because an empty container has a different tariff from a fully loaded container. Both empty and loaded container tariffs are included in the system.

- Port revenue from TS

Tongzon (2009) discussed two types of port charges; ship-based charges and cargo-based charges. Both charges are generally levied on the basis of the number of calls and the amount of cargo handled in the port.

A ship-based type includes port navigation fees, berth hire, harbour dues and tonnage. While, cargo-based types include wharfage and demurrage. The first type of charge can be calculated against gross registered tonnes (GRT), and the second type of charges can be determined by the rates that have been set by the port. Damietta port receive the revenue from total time a ship stays in the port (TS) that depends on both how long it stays and on the gross tonnage (GRT). The port and light dues involves tariffs for sub elements such as port dues, light dues wharfage dues, and cleaning dues.

Interviews with the port director and the port operations manager showed that the TS revenues are currently calculated by multiplying tariffs with GRT, except wharfage dues which is calculated by multiplying tariffs with GRT with OT. Revenues from TS include other elements such as towage fees, pilotage fees and port-state fees. It is important to note that special cleaning fees are charged at Damietta port because it is a green port. These fees can be excluded when the system applied in other ports such as Alexandria port.

- Port revenue from CT

Clearance charges vary according to tonnage and are not time dependent. They are known as agency fees include many elements; post office fees, Arabic translation fees, fees for crew permission documents, telecommunication costs, photocopy fees, customs, immigration office, medical insurance fees, $ 3 USD commission for container service per container (for containers only). The port revenues from CT can be calculated by multiplying the clearance tariffs with total cleared tonnes. This was made by the help of calling a custom inspector during the port visit.

Developing DAPEMS Using Flexibility Measures

In port studies, different flexibility measures were applied according to the purpose of measurement. Table 3: displays the flexibility measures that are commonly applied in ports.

Table 3: Flexibility Measures in Port Studies

Author	Focus (Flexibility Dimension)	Flexibility Measures
Chlomoudis and Pallis (1999)	Port Management	Scientific management, technologies, markets
Fourgeaud (2000)	Port Capacity	Commercial capacity output
Notteboom and Winkelmans (2001)	Port Capacity	Economics of scope
Tongzon and Heng (2005)	Port Throughput	Port management performance
Jara-Diaz et al (2006)	Port Capacity	Labour, space, storage and facilities
Diaz-Hernandez et al (2008)	Cargo Handling Flexibility	Labour and equipment
Notteboom and Rodrigue (2008)	Terminal Capacity	Storage and Handling

Plans refer to the possible port flexibility to allow a prompt response to changing demand. It identified these plans that should be considered in port flexibility, including a maritime traffic assignment plan, a national port investment plan, an inland routing plan, a coastal shipping plan, and port master plan. The recommendation was made to provide additional temporary facilities to maintain a port capacity in case of the growing traffic, and to provide operational plan and cargo handling methods to cope with growing volumes. Hence, port flexibility is mainly concerned with the short and long-term investment plans. Different solutions were proposed as contingency plans, including for example hiring mobile cranes from outside the port, speeding up the handling rates and reducing ship turn-around time. Notteboom and Winkelmans (2001) argued that a port is being chosen if it helps to minimise the sum of the sea, port and inland costs. It depends on a port's capacity to influence goods flow.

Marlow and Casaca (2003) proposed that ports should be agile which implies flexibility that allows for quick response to changes in customer demand and to grow in competitive markets. Jara-Diaz *et al* (2006) claimed that a port has many stakeholders and operations which require high flexibility in terms of coordination between them. They focused on coordination between labour, space, facilities and equipment in port operations. They argued that a port is a factory that provides services (inputs) to receive, dispatch and deliver cargo (outputs). Diaz-Hernandez *et al* (2008) focused on cargo handling flexibility because it involves all activities related to the movement of goods inside a port, namely labour flexibility and equipment flexibility.

Taneja *et al* (2010a, 2010b) argued that flexibility in ports can be incorporated in the infrastructure design and port planning. They argued that port performance measures are generally time and cost-related and they suggested some strategies to cope with uncertainties, such as improving flexibility for operations and vessel berthing.

As a performance measure, flexibility can be defined as optimising the movement of cargo and reducing turn-around time of ships. In Damietta port, OT and TS developed previously as time measures can be used to assist in measuring flexibility. In DAPEMS, flexibility measures will be incorporated with time and revenue measures and it will be divided into three layers, including physical infrastructure flexibility, operations flexibility and service flexibility. The first layer is the most static and it is related to the port construction (Taneja *et al*, 2010b). In the second layer, flexibility is concerning the clearance time and operations time relative to the volumes handled. The perception of flexibility for customers extends to the landside as well as to the waterside. The third layer displays that service flexibility is concerned with the ship turn-around time. Table 4: shows how the flexibility measures take place to calculate the port ability to respond to any changes.

Table 4: Equations Incorporating Flexibility Measures

Flexibility Layer	Measure
Physical infrastructure flexibility	Static
Operations flexibility	Clearance time (CT) relative to TTH Operations time (OT) relative to TTH
Service flexibility	A ship turn-around time (TS) relative to NCS

From Table 4: the port flexibility can be measured through operations flexibility and service flexibility. Equation 5 shows that both flexibility layers refer to the port flexibility.

$$PF = OF + SF \tag{5}$$

Where

PT = port flexibility

OF = operations flexibility layer

SF = service flexibility layer

OF and SF can be measured using TS, OT and CT. The question is how to measure flexibility relative to OT and CT in case of operations flexibility and relative to TS in case of service flexibility. As displayed in Table 4, TTH can be used in relative to OT and CT, while NCS can be used in case of TS. Increasing volumes handled in the port lead to increase the time required for loading and unloading shipments, and to increase other forms of time such as clearance time. Controlling these times to the minimum refers to the operations flexibility. There are many flexibility dimensions can be used to control these times as follows:

- handling rate (hr)
- handling methods (hm)

- equipment productivity (e)
- storage availability (sa)
- labour productivity (lp)
- volumes handled (vh)

Increasing the number of shipping calls may increase waiting time in anchorage area and in ports. Controlling a ship turn-around time to the minimum refers to the service flexibility. Also, there are many flexibility dimensions can be used in measuring service flexibility:

- berth length (bl)
- berth throughput (bt)
- handling rate (hr)
- labour productivity (lp)
- administrative procedures (ap)
- shift working-time (sw)

Equation 6 can be considered in the investment plan, master plan and contingency plans in Damietta port. It helps to assess the port's ability to cope with changing demand. It is used to calculate port flexibility relative to previous identified flexibility dimensions as follows:

$$PF = f\,(hr, hm, e, sa, lp, vh) + f(bl, bt, hr, lp, ap, sw) \quad (6)$$

Top managers at ports need to be involved from the beginning of the implementation of operations to provide agile port, that requires a new approach to quickly adapt the services provided (Marlow and Casaca, 2003).

- **DAPEMS Formulation**

DAPEMS was developed using time, revenue and flexibility measures. Tables 5 displayed DAPEMS. The system aims to help Damietta port management to predict, manage and control the port performance using time and revenue measures, while the equation 6 can assist ports' managers in their planning and managing their ports' facilities and resources.

Table 5: DAPEMS

Damietta						
Performance	Category	Type of Cargo	General Cargo	Dry Bulk	Liquid Bulk	Containers
Efficiency Dimension	Time Measures	OT	$OT_{gcm} = -2054 + 47.8\ NCS + 0.00468\ ST + 28.5\ BO$	$OT_{dr} = -1110 + 51.2\ NCS + 0.00159\ TTH + 0.00622\ ST$	$OT_{liq} = -6 + 43.8\ NCS + 0.00215\ TTH - 0.0137\ ST$	$OT_{con} = -815 + 14.9\ NCS + 11.1\ BO + 0.0540\ LDR - 0.00285\ ST$
		TS	$TS_{gcm} = OT_{gcm} + 2SD_{gcm} + BT_{gcm} + UBt_{gcm}$	$TS_{dr} = OT_{dr} + 2SD_{dr} + BT_{dr} + UBT_{dr}$	$TS_{liq} = OT_{liq} + 2SD_{liq} + BT_{liq} + UBT_{liq}$	$TS_{con} = OT_{con} + 2SD_{con} + BT_{con} + UBT_{con}$
		CT	CT_{gcm}	CT_{dr}	CT_{liq}	$CT_{con\ (loaded)} - CT_{con\ (empty)}$
	Revenue Measures	Revenue from OT/month (REVOT)	α_{gcm} * no of tonnes* OT_{gcm}	α_{dr} * no of tonnes*OT_{dr}	α_{liq} * no of tonnes*OT_{liq}	[α_{con} * no of container(loaded)+ (α_{con} * no of container(empty)] *OT_{con}
		Revenue from a ship stays in the port /month (REVTS)	TS revenues	Tariffs	(tonnes)	(time)
			Port Dues	0.21 $	* GRT	--
			Light Dues	0.05 $	* GRT	--
			Wharfage Dues	0.0125 $	* GRT	* time
			Cleaning Fees	120 $	--	--
		Revenue from CT/month (REVCT)	β_{gcm} *no of tonnes	β_{dr} *no of tonnes	β_{liq} *no of tonnes	[(β_{con} * no of container(loaded))+ (β_{con} * no of container(empty)]
		Total revenue/month	REVOT + REVTS + REVCT	REVOT + REVTS + REVCT	REVOT + REVTS + REVCT	REVOT + REVTS + REVCT
Effectiveness Dimension			Total Tonnes Handled	Total Tonnes Handled	Total Tonnes Handled	Total Tonnes Handled
Flexibility Measures			PF = f (hr, hm, e, sa, lp, vh) + f(bl, bt, hr, lp, ap, sw)			

Keys Used in DAPEMS

TS = total time a ship stays in the port - α = tariffs set for loading and discharging

CT = clearance time - β = tariffs set for clearance cargo

OT = operations time - REVOT = revenues generated from OT

NCS = number of calling ship - BT = berthing time

BO = berth occupancy - UBT = un-berthing time

TTH = total tonnes handled in a given period - SD = standing time

LDR = loading/discharging rate - REVTS = revenues generated from TS

ST = storage - REVCT = revenues generated from CT

GW = Gross Tonnage

SECTION 6 – CONCLUSIONS AND FURTHER RESEARCH

A wide range of measurement systems and frameworks have been developed for assessing a port performance. It is found that current measurement systems applied in ports are limited in quantifying port performance.

This paper sought to investigate how current performance measurement systems can be developed to measure the performance of ports. A quantitative approach was performed to develop the proposed system, named DAPEMS. The system started with time measures, and then it was extended using revenue and flexibility measures.

Further areas of research needs more investigated and study. Other categories of measures can be included into the system, such as quality measures and asset management. Other types of cargoes can be added into the system such as natural gas. This requires dedicated KPIs and measures rather than those used in the system. Also, future research can apply regressions on cost measurement, and organisational and administrative operations can be considered. In next paper, DAPEMS reliability in case of disturbances will be explained. Also, the system was tested for two months at Damietta port. The feedback will be discussed in further paper.

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