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The Development of a Port Performance Measurement System: With Reference to Damietta Port, Egypt

THE DEVELOPMENT OF A PORT PERFORMANCE MEASUREMENT SYSTEM:

With Reference to Damietta Port, Egypt

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Abstract

Ports compete through providing high quality services at the right price. Ports require reliable performance measurement systems so that their daily operations can be effectively managed, their port assets efficiently utilised, and cargo dwell and standing times minimised. Port performance studies have been approached from strategic, operational, functional, financial and managerial perspectives. Findings in the literature have concluded that the measurement systems currently used are limited because the focus is on measuring efficiency, especially for containerised cargo and terminals. Often, key variables have been ignored and there is focus on improving productivity rather than performance. This research addresses the issue of how current performance measurement systems can be developed to measure the performance of ports more effectively.

The research has been designed to contribute to knowledge through conceptualising the needs of developing effective measurement systems in ports by using relevant measures and quantifying those key predictors that influence a port's performance. Quantitative methods are traditionally used for assessing port performance. This research commences with a discussion of supply chain performance measurement systems in relation to ports. It investigates different supply chain measurement designs, categories and characteristics within each category and examines the effectiveness of the current measurement system applied in Damietta port, Egypt. Findings show that Damietta port currently has no formal measurement system and would benefit from the implementation of a performance measurement system. Data have been collected according to the four types of handled cargoes in Damietta port, namely general cargo, dry bulk, liquid bulk and containers. Data have been collected on a monthly basis. For each type of cargo, data have been edited and keyed and a categorisation scheme has been set up to cover those operations at terminals. The Damietta Port Performance Measurement System (DAPEMS) has been developed using three measures, including: time, revenue and flexibility measures. Initially the system was developed using time measures, where key determinants were discussed and multiple regression analyses applied. Relevant predictor variables were selected and incorporated into the regression models with varying degrees of significance. Following this, DAPEMS has been extended using revenue measures, where revenues resulted from operations time, clearance time and the time a ship stays in a port. The final measure considered was flexibility. This helps to cope with the complexity of operations and uncertainty at ports. DAPEMS has been tested for two months in Damietta Port. In addition, the system's features, including: reliability, applicability and flexibility have been analysed. The system was tested for two months at Damietta port. The port managers reported the benefits of using DAPEMS as there is no system currently applied in the port. Using additional variables, understanding the relationship between variables, providing information about port revenue and providing managers with estimated future performance were appreciated by the port director and a top manager as this helps them and the port planners in a decision-making process. It is concluded that applying DAPEMS was highly appreciated for providing useful visibility about the port's performance. However, some limitations are addressed and suggestions are proposed to be carried out for future research.

Copyright Statement

Dedications

To my mother's spirit, my wife and my two children who have morally supported me with their unlimited love throughout my study at the University of Huddersfield,

I dedicate this work

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supported me in any respect during the completion of the research.

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List of Abbreviations

Symbol	Abbreviation
ABC	Activity Based Accounting
BLUE	Best Linear Unbiased Estimator
BO	Berth Occupancy
BPR	Business Process Reengineering
BSC	Balanced Scorecard
BT	Berthing Time
CT	Clearance Time
DAPEMS	Damietta Port Performance Measurement System
DCHC	Damietta Container and Cargo Handling Company
DEA	Data Envelopment Analysis
DMU	Decision Making Units
DPA	Damietta Port Authority
EDI	Electronic Data Interchange
EMDB	Egyptian Maritime Data Bank
EMS	Environmental Management System
ETA	Event Tree Analysis
FDH	Free Disposal Hull
FEU	Forty foot Equivalent Unit
FTA	Fault Tree Analysis
GDP	Gross Domestic Production
GRT	Gross Tonnage
H_A	Alternative Hypothesis
H_N	Null Hypothesis
ICAS	Institute of Chartered Accountants of Scotland
IMO	International Maritime Organisation
ISPS	International Ship and Port Security
JICA	Japan International Cooperation Agency
JIT	Just-in-time
KGL	Kuwait and Gulf Link Holding Company

KPI	Key Performance Indicator
LDR	Loading and Discharging Rates
MTS	Maritime Transport Sector
NCS	Number of Calling Ships
NVIC	Navigation Vessel Inspection Circular
OLS	Ordinary Least Square
OOBM	Object Oriented Business Model
OT	Operations Time
PCA	Principal Component Analysis
PMQ	Performance Measurement Questionnaire
PMS	Performance Measurement System
PPI	Port Performance Index
PPVC	Performance Planning Value Chain
PQM	Process Quality Model
RTG	Rubber Tire Gantry
SADT	Structured Analysis and Design Techniques
SCOR	Supply Chain Operations Reference
SD	Standing Time
SFA	Stochastic Frontier Analysis
ST	Storage
TEU	Twenty foot Equivalent Unit
TEU (e)	Empty container
TEU (f)	Full-loaded container
TQM	Total Quality Management
TS	Total Time a Ship Stays in Port
TTH	Total Tonnes Handled
UBT	Un-berthing Time
UNCTAD	United Nations Conference on Trade and Development
VIF	Variance Inflation Factor
VRS	Variable Return to Scale
WTO	World Trade Organisation

List of Publications

The research carried out and presented in this doctoral thesis has partly been published in the following earlier publications.

- EL-Sakty, K., Tipi, N., Bamford, C. and Hubbard, N. (2008) *Port supply chain performance measurement analysis.* In: Logistics Research Network Annual Conference 2008, 10th-12th September 2008, University of Liverpool, UK.
- EL-Sakty, K., Tipi, N., Hubbard, N. and Bamford, C. (2009) *Developing a supply chain performance measurement system: case study of Damietta Port in Egypt.* In: 14th International Symposium on Logistics, 5th - 8th July 2009, Istanbul, Turkey.
- EL-Sakty, K. (2011) *The maritime impacts of political changes in the East Mediterranean: optimising port performance (Egyptian experiment).* In: 2nd ESPO conference 2011, 5th-6th May 2011, Limasol, Cyprus.

Posters submitted to the University of Huddersfield during conducting the research:

- EL-Sakty, K., Tipi, N., Hubbard, N. and Bamford, C. (2008) *An Evaluation of Port Supply Chain Performance Measures*. Poster, 27th February 2008, University of Huddersfield, U.K.
- EL-Sakty, K., Tipi, N., Hubbard, N. and Bamford, C. (2009) *Developing a More Effective Port Performance Measurement System*. Poster, 18th March 2009, University of Huddersfield, U.K.
- EL-Sakty, K., Tipi, N., Hubbard, N. and Bamford, C. (2010) *A quantitative approach towards developing an effective performance measurement system in Damietta port*. Poster, 24th February 2010, University of Huddersfield, U.K.
- EL-Sakty, K., Tipi, N., Hubbard, N. and Bamford, C. (2011) *Measuring performance of operations at ports*. Poster, 18th March 2011, University of Huddersfield, U.K.

Chapter One

Introduction

1.1 Introduction to the Research Topic

Technological development and scientific research has led to a rapid growth in international trade and the exchange of products between countries (Siebert, 1999). Between 2009 and 2010, the developed economies witnessed an expansion in imports and exports by 11.5% in volume terms, while the rest of the world increased by 16.5% (WTO, 2010). As indicated in the World Trade Organisation (WTO) report in 2010, the foreign trade of commodities and services at the global level also increased by 13.5% over the same period. The demand for seaborne trade is derived from the demand for international trade (Feenstra, 1998; Stopford, 2004; Lun et al., 2010). In fact, about 90% of world trade is transported by sea in volume terms and almost 80 % in value terms (Branch, 1997; IMO, 2009; Zouari and Khayech, 2011), and ports are considered as a necessary element for facilitating seaborne trade (Tongzon et al., 2009; Simoes and Marques, 2010). Weak port performance results in reduced trade volumes (Blonigen and Wilson, 2008). Hence, it is important to continually improve the performance of the primary elements of the maritime industry, namely ports, cargoes and ships (Abdella and Abdelhafez, 2000).

The first element, ports, respond to this increased demand for seaborne trade through increased port capacity and improved port performance (Ramos-Real and Tovar, 2010). Ports' managers face challenges to enhance port competitiveness through providing quality services to port clients, reducing total operating costs, improving port performance, and satisfying all port clients including stevedoring companies, ships, shipping lines, exporters, importers, forwarders, ship owners, carriers and shippers (Sharma and Yu, 2010).

Cargoes are the second element where world trade comprises hundreds of different types of commodities shipped by sea. These include raw materials such as oil, industrial materials such as cement, and manufactured products such as machinery. Accordingly, ship types and designs have been developed to meet world trade needs and the types of cargoes being transported.

For the ship element, many sizes of ship are required to deal with different parcel sizes, water depths, long-haul routes, and to keep the sea transport cost low. Hence, many shipyards have adopted new ship designs through increasing the size and number of holds, for example, to benefit from economies of scale. General cargo ships are still considered the largest single category among other types of ships carrying different types of cargo. Tankers are the second largest category where high load-carrying capacity ships have been built to carry various types of liquefied products, such as natural gas. Other types of ship play an indispensable role in seaborne trade, such as bulk carriers that carry heavy and high density products, and container ships that carry standard units which support multimodal transport.

In Egypt, ports are considered to be the backbone of the country’s foreign trade and support for economic development. In 2010, seaborne trade represented 90% of the total volume of Egyptian foreign trade, where the ports received 19,680 ships and handled approximately 132.7 million tonnes, up 9% compared to 2009 (EMDB, 2011). In 2009, Egypt had a 0.64% share of world total exports, a 0.41% share of the world's total imports and a 0.2% share of the world maritime merchant fleet (WTO, 2011). New Egyptian ports have been built to meet the high volume of trade such as, East-Port Said port. Old ports are being modernised and expanded such as, Alexandria port and Damietta port. Specialised ports have been upgraded such as, Sokhna port. Finally, the Suez Canal has been dredged to 66 feet, in 2010, to allow larger vessels to pass and the Suez Canal terminal has been planned.

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 (Simoes and Marques, 2010). They are responsible for selecting warehousing locations and capacities, determining the number of cranes, derricks, winches, forklifts and any other cargo handling equipment required for loading and discharging cargoes and controlling daily port operations. Also, managers are responsible for using information systems for demand forecasting, strategic planning, port control, and customer satisfaction (Panayides and Song, 2008). Determining how many shifts per day and reducing waiting times in port or at berths are also part of port managers' responsibilities.

The diversity of port managers' responsibilities, the complex market structure of the port industry, and the challenge of managing port facilities require the use of 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 have been undertaken in relation to port economics, port policy, port management, port terminals and port planning in order to evaluate port performance (Pallis et al., 2011).

1.2 The Importance of Performance Measurement

Performance measurement is important to the efficient and effective management of organisations. It reflects an organisation's objectives, customer requirements and the external competitive environment (Kennerley and Neely, 2002). It can be used to assess the success of organisations. Understanding performance can also affect the behaviour of managers and employees (Kaplan and Norton, 1992). Bruijn (2002) discussed how performance measurement can fill a number of functions, including transparency, learning, sanctioning, appraising and benchmarking between organisations and competitors.

Performance measurement helps decision makers through capturing performance data. Managers rely on measures as an integral element of planning and controlling processes (Neely et al., 1997). In a supply chain context, measuring performance is a managerial tool that assists in planning and organising activities, motivating workpeople, and controlling events within acceptable parameters (Morgan, 2004).

In any business enterprise, performance measurement becomes an important factor for effective planning and decision making (Chan, 2003; Chan et al., 2003). It can provide necessary feedback information to reveal progress, enhance communication and diagnose problems (Waggoner et al., 1999; Brooks et al., 2010). Furthermore, it can help to understand the integration among the supply chain components.

In port studies, the performance of each element of the maritime industry influences seaborne trade, and consequently international trade. 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. An efficient performance measurement system 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 the management of complicated operations.

Ports' managers, planners and authorities need a reliable performance measurement system to assess the efficiency and effectiveness of their actions. For this reason, optimisation of facilities and operations is the common goal in most current measurement systems. 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. A range of measurement systems are currently used in ports and terminals.

1.3 Towards a New System of Performance Measurement

The literature indicates that there is a gap in knowledge as traditional and recently developed measurement systems tend to be inconsistent, and lack the focus of measuring overall port performance. Most systems measure containerised cargoes, container ports and container terminals. A port has many terminals and normally handles more than one type of cargo: dry bulk, liquid bulk, containers and general cargo. A focus on measuring one type of cargo does not reflect overall port performance. Hence, recent measurement systems are not able to meet a port's strategic focus.

Tongzon (1995, p. 245) claimed that "few studies identified those measures and factors that influence port performance and that these have failed to quantify those factors for overall performance". Kennerley and Neely (2002) argued that the evolution of measurement systems over time remains a considerable gap in performance measurement research.

Bichou and Gray (2004) stated that:

> "It appears that there may be a methodological difficulty in linking supply chain performance measurements to ports. A systemic approach to port performance is required" (Bichou and Gray, 2004, p. 53).

There is a need to develop a more effective performance measurement system. This system needs to be clearly linked to the port operational strategy and related to a number of key performance variables.

1.4 Research Outline

Figure 1.1 shows the conceptual framework of the research. Port performance measurement has a role in planning and controlling port's operations. A literature review was conducted to conceptualise the design of performance measurement systems in ports. Findings concluded that current measurement systems are limited and there is a need to develop a reliable measurement system to fill this gap. Therefore, the research question has been set to contribute to the development of knowledge and the approach has been set as a deductive approach where a quantitative study has been applied.

Quantitative methods are traditionally used for assessing port performance (Marlow and Casaca, 2003). Various techniques have been used including: econometric techniques, engineering techniques, operation research techniques, statistical techniques, simulation models, queuing models, mathematical models and regression analysis (Tongzon, 1995; Tongzon and Heng, 2005). The research is designed to discuss the current measurement systems applied in ports and to assess the effectiveness of Damietta port's current performance measures.

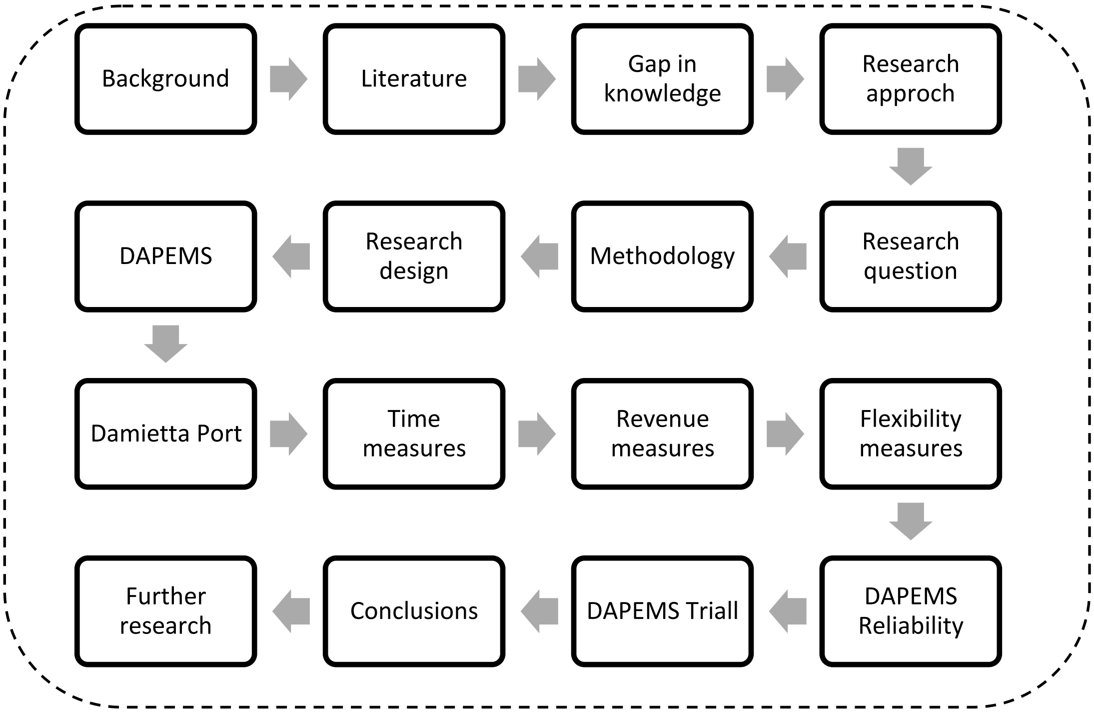


Figure 1.1 Conceptual Framework of the Research

The development of the Damietta Port Performance Measurement System, named DAPEMS, will form the focus for this investigation. The system was developed using time measures, and then, other measures are applied using revenue and flexibility measures. Testing the system's applicability, reliability and flexibility were discussed and the conclusions and recommendations summarised. In Chapter Three, the research philosophy, strategy, process and methodology will be explained in detail.

1.5 Research Problem and Hypothesis

This research addresses the need for port managers and planners to develop a reliable and effective performance measurement system. These systems can help port managers to predict, control and plan their port and, consequently, improve their competitiveness. The research problem has directly addressed the gap in knowledge and it has set the following problem to be investigated:

How can current performance measurement systems be developed to measure the performance of seaports more effectively?

To answer the research problem, the research has set out to test the following hypothesis:

Developing a more effective performance measurement system will lead to improved performance in Damietta port

The null and alternative hypotheses are hereby put forward as H_N and H_A:

- **H_N:** developing a more effective performance measurement system will not lead to improved performance in Damietta port.

- **H_A:** developing a more effective performance measurement system will lead to improved performance in Damietta port.

1.6 Research Aims and Objectives

The scope of this research is to develop a more effective measurement system for the purpose of assessing a port's performance. In order to test the hypothesis, the research has the following aims:

1. To discuss the current supply chain performance measurement systems and models applied to ports.
2. To investigate the effectiveness of the current performance measurement system in a port and to understand those variables that influence a port's performance.
3. To develop a measurement system to be used in Damietta port, named Damietta Port Performance Measurement System (DAPEMS).

4. To evaluate the extent to which DAPEMS can be applied to other Egyptian ports or elsewhere.

The above aims show that the research is intended, in large part, to develop a more effective measurement system. In order to address the key aims, the research has set the following objectives:

1. To discuss the characteristics, designs and categories of current supply chain performance measures and the classification of performance measurement systems.
2. To study the supply chain models currently applied in ports.
3. To examine the current measurement system applied in Damietta port as a case study and to evaluate its effectiveness.
4. To analyse limitations that are associated with the current Damietta model.
5. To develop DAPEMS using time measures.
6. To develop DAPEMS using revenue and flexibility measures.
7. To test the reliability, applicability and flexibility of DAPEMS.
8. To define the limitations of DAPEMS and provide insights for future research.

1.7 Research Methodology

The research methodology is a deductive methodology for two reasons: philosophical and practical implications. A deductive methodology helped to study a sample of population at Damietta port to test the hypothesis.

The philosophical justification exists in the review of literature that has produced reoccurring themes emphasising the importance of quantifying predictor variables in ports. There are extensive overviews of conceptually oriented papers on the optimisation of operations in ports (Bichou, 2007; Pallis et al., 2010). These studies focused on using operational research techniques for optimising port operations. However, the literature survey verified that no single performance measurement system is recommended as a standard tool to measure a port's performance.

For practical implications, a deductive methodology is more appropriate to fit the nature of operations in ports (Pallis et al., 2009). There are predictor variables that influence a port's performance. These predictors comprise complicated operations for different types of cargoes at different terminals.

A quantitative methodology is relevant to investigate the efficiency and productivity issues where operations can be quantified to evaluate port performance.

Various methods have been used in this research for the purpose of collecting reliable data to measure current Damietta port performance and for those variables used in developing DAPEMS. Different methods of data collection, using both primary and secondary sources, have been applied. The research methods are discussed in detail in Chapter Three.

Damietta port is the case study used in this research. The reasons for selecting Damietta port as a case study are discussed in Chapter Three. Data have been analysed as a series of steps for developing DAPEMS. They are:

1. Developing DAPEMS required a reliable problem-solving technique. In support of this, a case study has been used as it provided contextual analyses of similar operations in other Egyptian ports. The main benefit of the case study was that it improved the hypothesis investigation and it was useful for understanding certain phenomena of common problems in ports.
2. A full set of data has been collected by the researcher directly from the port records system.
3. Data have been collected in a variety of ways and from different sources including primary and secondary sources such as interviews. This is to verify the accuracy and reliability of data.
4. Time series data have been gathered for Damietta port operations on a monthly basis.
5. Data covered key performance variables in Damietta port including; storage areas, transportation, cargo handling rates and berth occupancy.
6. Data have been organised per type of cargoes into four groups; general cargo, dry bulk, liquid bulk, and containers.

7. Data have been collected on a monthly basis for five years starting from January 2004 to December 2008, 60 samples in total.

1.8 Structure of the Research

The research structure shows the plan that has been undertaken to test the hypotheses, answer the research question and achieve the aims and objectives. It has been structured to develop a measurement system named DAPEMS. A brief overview of the key chapters in this research is presented in Table 1.1 below.

Table 1.1 Overview of Chapters in the Research

Content Overview
Chapter One Starts with an introductory chapter to set out the research problem, hypothesis, aims and objectives.
Chapter Two Reviews current supply chain performance measurement systems and models applied in ports. This then led to a comprehensive discussion of those measurement systems and approaches applied in ports. It concludes with the weaknesses and limitations of current measurement systems and the need to develop a reliable approach to improve port performance.
Chapter Three Discusses relevant aspects of the research methodology and methods used in developing the measurement system.
Chapter Four Examines the effectiveness of the current measurement system applied in Damietta port, and presents the limitations of the current measurement approach.

Chapter Five Applies multiple regression analysis as a method to determine the significance of relationships between predictor variables and port performance. It helps in designing DAPEMS using time measures.
Chapter Six Develops DAPEMS using both: revenue and flexibility measures. It helps to cope with the complexity of the port operating environment.
Chapter Seven Explains the reliability, applicability and flexibility as features of DAPEMS. Also, it provides feedback on the DAPEMS trial at Damietta port.
Chapter Eight Summarises the research and gives policy implications of these findings before concluding the research by acknowledging its limitations and highlighting potential areas for future work.

1.9 The Relationship between the Research Aims, Methods and Structure

This deductive research developed DAPEMS to increase the understanding of port performance and certain problems that commonly occur in Damietta port. Table 1.2 points out how the aims of the research have been met by using these multiple data sources and different methods.

Table 1.2- The relationship between the research's aims and the structure

RESEARCH AIMS		APPLIED METHODS	CHAPTER
1	To discuss the current supply chain performance measurement systems and models applied to ports.	▪ Literature search ▪ Library records	Chapter Two
2	To investigate the effectiveness of the current performance measurement system in a port and to understand those variables that influence a port's performance.	▪ Original investigation ▪ Case study ▪ Governmental publications ▪ Port visits ▪ Interviews	Chapter Four
3	To develop a measurement system to be used in Damietta port, named Damietta Port Performance Measurement System (DAPEMS).	▪ Observation ▪ Regression analysis ▪ Port visits	Chapter Five Chapter Six
4	To evaluate the extent to which DAPEMS can be applied to other Egyptian ports or elsewhere.	▪ Interviews ▪ Port visits	Chapter Seven

1.10 Chapter Summary

Chapter one has presented the importance of performance measurement in ports for monitoring daily operations and to cope with complexity. This research aims to develop a performance measurement system named DAPEMS. A deductive approach is considered relevant for this purpose due to philosophical and practical implications. The conceptual framework of the research has been found in the literature toward developing a quantitative approach for measuring a port's performance. In the next part, Chapter Two will discuss in detail different performance measurement issues from a theoretical perspective based on the literature.

Chapter Two

Supply Chain Performance Measurement and Port Studies

2.1 Introduction

Over the last twenty years, researchers have shown an increasing interest in improving performance measurement systems (Eccles 1991; Kaplan and Norton, 1992; Beamon, 1999; Neely et al., 1995; Neely, 2005; Elazony et al., 2011). Performance measurement studies come from a wide variety of different disciplines, including accounting, engineering, economics, human resources, marketing, sociology and management (Marr and Schiuma, 2003).

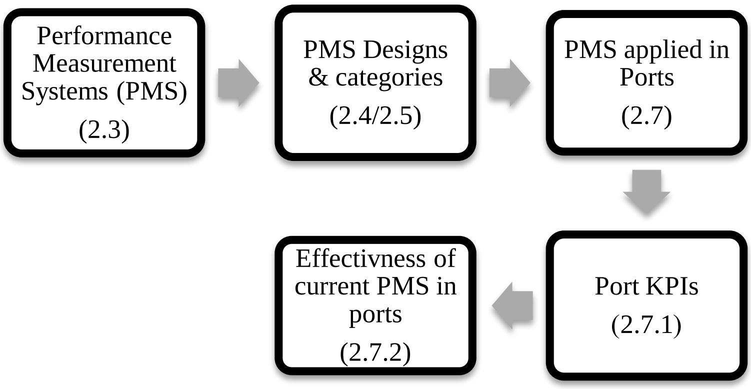


Figure 2.1 Literature Structure

Figure 2.1 shows the structure of the literature review. This commences with an analysis of performance measurement systems (PMS). It analyses the current performance measurement systems applied in the context of supply chains. The different concepts of performance, performance measure and performance measurement systems are explained. The discussion focuses on explaining the different designs of performance measurement systems and various categories of performance measures. Following this, an evaluation of current performance measurement systems used within ports is conducted. An evaluation of regression models and other analytical tools used in quantifying the factors that can affect performance within ports is also considered.

2.2 Literature Review

In a supply chain context, suppliers, manufacturers, distributors and customers are interlinked by a network that provides a reliable flow of information and materials. Hence, supply chains can be characterised by their complexity and uncertainty in their operations (Beamon, 1999; Beamon and Chen, 2001). Modelling such supply chains is challenging. In order to quantify supply chain performance in any business enterprise, it is necessary to identify what is meant by, and distinguish between, performance, performance measurement, performance measure and performance measurement system.

2.3 Performance Measurement

Performance has many definitions. Mentzer and Konrad (1991) have defined it as the ratio of actual output to standard output, which requires establishing a goal and a strategy to meet such standard output. This definition was based on differentiating between productivity, utilisation and performance. They discussed that productivity refers to the ratio of output to input, while utilisation is the ratio of used facilities to available facilities. In order to meet a standard output, a goal tends towards minimising operating costs and improving the service levels requiring a balance between efficiency and effectiveness. For both these dimensions, they measured efficiency in terms of how well the resources are utilised, while the effectiveness has been measured if a goal or a strategy has been accomplished.

Neely et al. (1995) defined performance as the efficiency and effectiveness of actions within a business context. Marlow and Casaca (2003) generally defined performance as:

> "An investigation of effectiveness and efficiency in the accomplishment of a given activity and where the assessment is carried out in relation to how well the objectives have been met" (Marlow and Casaca 2003, p.192).

Examining previous definitions of performance, it is obvious that performance has two dimensions (Neely et al., 1995): effectiveness and efficiency. Effectiveness aims to meet customer requirements, while efficiency is a measure of how economically a firm's resources are utilised.

For performance measurement, Mentzer and Konrad (1991) defined it as an analysis of efficiency and effectiveness of a given task. Neely et al. (1995, p. 1228; Bourne et al., 2003) defined performance measurement as "the process of quantifying the efficiency and effectiveness of action". They argued that a performance can be a process used to quantify efficiency and effectiveness (Tangen, 2004; Chan, 2003; Valmohammadi and Servati, 2011).

Beamon (1998b) emphasised that performance measurement is an examining tool of efficiency and effectiveness of an existing or proposed system. Measurement can take place by determining the value of the decision variables that yield the level of performance.

Lohman et al. (2004) defined performance measurement as an activity that managers can use to perform their predefined goals. Hence, they claimed that a selection of performance measures should be derived from a company’s strategy and objectives. Morgan (2004, p.522) defined performance as predetermined parameters and defined performance measurement as an ability to monitor activities in a meaningful way. Braz et al. (2011) defined performance measurement as the process of quantifying efficiency and effectiveness of actions of part of a system or a process.

For performance measure, Neely et al. (1997) defined it as an integral element of the planning and control cycle in organisations and it can be used to quantify the efficiency and effectiveness of action. Neely et al. (1995), Bourne et al. (2003) and Tangen (2004) defined it as a metric used to quantify the efficiency and effectiveness of action.

For performance measurement system, it can be defined as the set of metrics used to quantify both the efficiency and effectiveness of an action (Neely et al., 1995; Tangen, 2004). Bititci et al. (1997, p.533) defined a performance measurement system as “an information system which is of critical importance to the effective and efficient functioning of the performance management”. Neely et al. (2002) defined a performance measurement system as a balanced and dynamic system that enables support of the decision-making process by gathering, elaborating and analysing information. Bourne et al. (2003) claimed that a performance measurement system is a multi-dimensional set of performance measures for the planning and management of a business. They defined a system as a set of metrics used to quantify the efficiency and effectiveness of an action.

Braz et al. (2011) defined a performance measurement system as a set of measures used to measure the performance of actions taken. Three stages are required to develop a new performance measurement system, including design, implementation and use. Also, they argued that adding new measures to existing measures in any system will increase complexity and consequently, it will lead to outdated systems. However, increasing the number of measures helps to define the scale because a measurement system depends on the extent of items and variables (Brahma, 2009). Also, increasing the number of measures in a system helps to provide more information about all aspects of utilities in the port (UNCTAD, 1976; Tongzon, 1995; Fourgeaud, 2000; Marlow and Casaca 2003; Bichou and Gray 2004; Cullinane et al 2004; Gray, 2005; Taylor 2007).

Different approaches to measuring performance have been developed using different techniques and metrics to produce systems and frameworks, such as balanced scorecard (BSC) (Kaplan and Norton, 1992), performance pyramid (Lynch and Cross, 1990), the macro process model (Brown, 1996), the performance prism (Neely et al., 2002) and a macro-micro framework of performance measurement (Rouse and Putterill, 2003).

Franco-Santos et al. (2007) argued that none of the definitions of performance measurement systems has a consistent set of characteristics. Hence, it is necessary to understand the characteristics of performance measurement. In the following section, different measurement characteristics, categories and designs will be explained.

2.4 Categories of Performance Measures

A large number of different types of performance measures have been used to characterise systems such as consistency, cost, customer responsiveness, activity time and flexibility (Beamon, 1999). Previous research has focused on categorising performance measures, such as cost and quality. Understanding the measurement characteristics and categories of performance measures helps decision makers analyse, manage and control measurement systems, and upgrade performance measurement systems to fit the dynamic environment of businesses.

In other words, measurement characteristics can be used to evaluate a performance measurement system (Braz et al., 2011). Neely et al. (1995) identified four key questions in order to analyse the characteristics of a performance measurement system:

1. What performance measures should be used?
2. What are they used for?
3. How much do they cost?
4. What benefit do they provide?

Beamon (1999) identified four other important questions to examine the characteristics of a performance measurement system:

1. What to measure?
2. How are multiple individual measures integrated into a measurement system?
3. How often to measure?
4. How and when are measures re-evaluated?

Beamon (1996, cited by Beamon (1999)) identified inclusiveness, universality, measurability and consistency as the main characteristics of effective performance measures. Beamon (1999) identified three types of measures as the main components of a performance measurement system, namely resource measures, output measures and flexibility measures.

Azzone et al. (1991) identified simplicity and relevance as being two characteristics of effective performance measurement. They focused on keeping the complexity of the system low. For performance measurement categories, Table 2.1 summarises the different performance measure categories that have been developed over the years.

Table 2.1 – Categories of Performance Measures

Author	**Categories**
Keegan et al. (1989)	▪ Quality measures ▪ Speed measures ▪ Customer satisfaction measures ▪ Cost measures ▪ Cash flow measures
Kaplan (1990)	▪ Shipments measures ▪ Inventories measures ▪ Labour performance measures ▪ Capital measures ▪ Spending measures ▪ Variances measures ▪ Headcount measures
Maskell (1991)	▪ Cost measures
Neely et al. (1995)	▪ Quality measures ▪ Time measures ▪ Flexibility measures ▪ Cost measures

Beamon (1998)	▪ Qualitative measures ▪ Quantitative measures
Beamon (1999)	▪ Cost measures ▪ Cost and customer responsiveness measures ▪ Customer responsiveness measures ▪ Cost and activity time measures ▪ Flexibility measures
Shepherd and Gunter (2006)	▪ Quantitative and qualitative measures ▪ Cost and non-cost measures ▪ Quality, time, flexibility and innovation measures

Different performance measures categories were developed according to a range of characteristics. From an organisation's strategic perspective, Neely et al. (1995) presented a few categories including: quality, time, flexibility and cost. Maskell (1991) identified cost as the sole performance measurement category. On the other hand, Keegan et al. (1989) argued that the best approach was to start with five generic measurement categories as shown in Table 2.1.

Previous categories aimed at understanding the organisation's cost drivers. It is observed that these categories include cost as a principal measure in the performance measurement system. The aim is to make a business enterprise more efficient by managing production costs and the cost of service provided and cash flow. However, these measures are directed to manufacturing strategy, which are neither applicable in other organisations, nor supporting other strategies within the same organisation.

Thus, Dixon et al. (1990) developed a performance measurement questionnaire (PMQ). However, PMQ did not present a clear category of measures. It was based on judgement and experience of respondents rather than what happens in reality. Kennerley and Neely (2003) defined four categories of capabilities that organisations must follow to manage their performance, namely processes, people, culture and systems.

The process category aims to review measures, while the people category concerns the required skills to use measures. Culture capability proposes an appreciation of the importance of measures, and the systems category discusses the organisation's capability to collect, analyse and interpret data.

2.5 Performance Measurement Design

Neely et al. (1997) argued that the design of a performance measurement system is a process where inputs and outputs are produced. Inputs are captured in the form of requirements and outputs are produced in the form of a performance measure. They developed a performance measurement record sheet to help in structuring a measurement framework and in facilitating the design of performance measurement systems.

Globerson (1985) stated that the design of a performance measurement system must fit the company's objectives. Maskell (1989) offers the following seven principles of performance measurement system design:

1. The measures should be directly related to the firm's strategy.
2. Non-financial measures should be adopted.
3. It should be recognised that measures vary between locations.
4. Measures change as circumstances do.
5. The measures should be simple and easy to use.
6. The measures should provide fast feedback.
7. The measures should stimulate continuous improvement rather than simply monitor.

Neely et al. (2000) focused on the importance of selecting a relevant design for performance measurement systems. A measurement system should include financial and non-financial measures. They identified the performance measurement systems design principles on the importance of deriving measures from a company's strategy (Tangen, 2004; Morgan, 2004). Measures must be explicit and clear, and measures must be easy to use.

However, they argued that the literature is concerned with the rules and guidelines for designing performance measurement systems, rather than the actual output of the process. Hence, they identified 12 principles for a performance measurement system design process.

Bourne et al. (2000) proposed three phases for developing performance measurement systems, including the design of the performance measures, the implementation of measures and the use of performance measures. The design phase aims to identify the key objectives to be measured. The implementation phase determines which systems and procedures are applied to collect and process the data, while the use phase aims to use the information and feedback from the measures to test the validity of the strategy. Bourne et al. (2002) identified the success and failure factors of performance measurement system design, including: contextual factors such as, lack of leadership; process factors, such as identifying the right measures; and content factors such as, poorly defined metrics.

Bourne et al. (2003) categorised performance measurement design processes into two broad categories: procedure design and approach design. The procedure design can take one of the following forms:

1. Needs led design, where the needs of customer, business and stakeholder are the basis of the system, such as the balanced scorecard.
2. Audit led design, where systems start with the audit of existing performance measures, such as PMQ.
3. Model led design, where a theoretical model is applied for designing performance measures.

Bourne et al. (2003) described approach design as follows:

1. Consultant led design, where the work of consultants are reviewed and incorporated into designing systems.
2. Facilitator led design, where the work of the management team is used when designing systems.

The literature shows that the performance measurement systems can be examined according to three different designs: individual design, multiple design and matrix design.

2.5.1 Individual performance design

The first performance measurement system design has an individual form of measurement where a single measure is used. Beamon (1999) claimed that a single measure is attractive because of its simplicity. Neely et al. (1995) focused on the most important measures used in individual design, including quality, time, cost and flexibility measures as shown in Figure 2.2. Each of these measures has different dimensions.

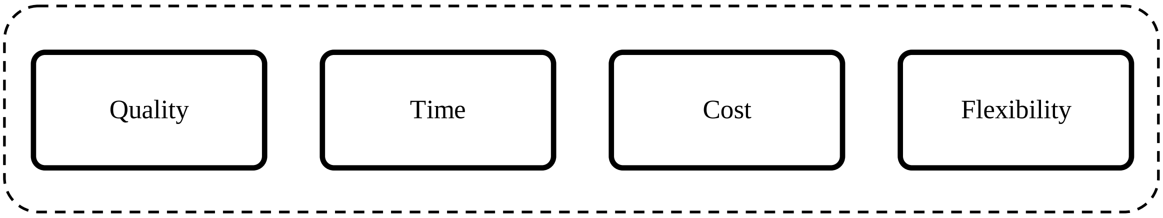


Figure 2.2 – Important Measures of Individual Design

For quality measures, some performance measurement systems are designed to find the cost of quality which is a measure of the extra cost incurred by the organisation because it is either under or over-performing. Also, some measures of quality include statistical process control for assessing the process rather than the output. Beamon and Ware (1998) developed the Process Quality Model (PQM) for assessing, improving and controlling the quality of the supply chain process. PQM comprises eight modules and it aims to evaluate the overall quality of the supply chain system. Regarding measures relating to time, Drucker (1990) has developed a time-based costing system known as throughput accounting. The throughput accounting system should be measured in terms of the rate at which money is received rather than as an absolute. In manufacturing industries, time measures were an important source of competitive advantage. Manufacturing lead time, delivery lead time and frequency of delivery are examples of dimensions of time measures (Neely et al., 1995).

Azzone et al. (1991) focused on using time measurement as a fourth dimension of competition alongside quality, cost and innovation. They suggested a performance measurement system called the matrix, which is consistent with time- based principles.

Regarding cost measures, accounting principles were widely applied in different performance measurement designs (Kennerley and Neely, 2002). Feigenbaum (1961, cited by Neely et al., 1995) defined the cost of quality as a function of the prevention, appraisal and failure costs. Prevention costs refer to those efforts to prevent discrepancies such as training programmes. The appraisal costs refer to those costs spent in the detection of discrepancies such as inspection costs, while failure costs refer to those costs as a result of discrepancies such as customer complaints.

Beamon (1998) identified different objectives for those measures that are based on cost, including cost minimisation, sales maximisation, profit maximisation, inventory investment minimisation and return on investment maximisation. Neely et al. (1995) proposed service cost and manufacturing cost as examples of cost measures dimensions.

Regarding measures relating to flexibility, Slack (1983) identified cost and time as dimensions of flexibility. Neely et al. (1995) discussed various flexibility measures, such as volume flexibility, material flexibility and modification flexibility.

Unfortunately, an individual performance measure is not inclusive, as it does not reflect the real performance of business enterprises (Beamon, 1999; Kaplan and Cooper, 1998). Kennerley and Neely (2002) argued that using financial measures, as the sole criterion, for example, is no longer relevant for organisations due to their increased complexity.

2.5.2 Multiple performance design

Kaplan and Cooper (1998) discussed the use of multiple performance design, such as activity-based costing (ABC) systems. They claimed that multiple designs provide visibility of the economics of their operations. The focus was on using multiple cost systems to provide more responsive, more accurate and more relevant information for serving companies. However, cost measures were the main measures in systems with no regard paid to non-financial measures.

The second performance design has a multiple form of measures. Neely et al. (2002) argued that the individual performance design is not applicable to view business performance, because business performance is itself a multi-faceted concept. Thus, they established a framework that is called the performance prism.

The performance prism has five facets. The top and bottom facets are stakeholder satisfaction and stakeholder contribution. The three other facets are strategies, processes and capabilities. The prism illustrates the complexity of performance measurement and management. Neely et al. (2002) believed that a single measure offers a unique perspective on performance.

Their prism offers multiple and interlinked perspectives on performance. However, the prism did not show how these can be achieved in reality. Additionally, the prism does not have consistency between its components, as the stakeholders' expectation may exceed the set level of performance.

2.5.3 Matrix performance design

The last form of performance design takes a matrix framework. Keegan et al. (1989) proposed a performance measurement framework that is known as the performance measurement matrix. As with the balanced scorecard, its strength lies in integrating different dimensions of performance, and it employs internal, external, cost and non-cost terms in enhancing its flexibility. The performance measurement systems can be established either in a simple matrix or more detailed quality diagrams. However, the matrix performance measures lack consistency between the different dimensions of business performance, like multiple measures.

2.6 Supply Chain Performance Measurement Systems

In a supply chain context, different performance measurement systems have been recently developed using different techniques and for different purposes. The Balanced Scorecard is the most widely applied system (Braz et al., 2011). Kaplan and Norton (1992) provided a measurement concept to integrate financial and non-financial indicators in a first generation balanced scorecard approach (BSC). Their management concept is aimed at the internal evaluation of a business enterprise from four different perspectives: the financial perspective, the customer perspective, the internal business process perspective and the learning and growth perspective. It gives top managers a fast and comprehensive view of their businesses, as it is a balanced presentation of both financial and operational measures.

However, Paranjape et al. (2006) claimed that the balanced scorecard is limited in that: it focuses only on managerial needs; is not service-oriented; it fails to indicate the competitors' perspective; people, suppliers, environmental and social issues are omitted. Hence, the second generation of BSC approaches focused on the cause-and–effect relationships between measures using a strategy map, while the third generation BSC is about developing strategic control systems instead of the traditional four perspectives (Valmohammadi and Servati, 2011).

Neely et al. (2002) developed a performance prism framework that comprised five integrated perspectives as discussed earlier. They argued that the prism helps to understand the complexity of performance measurement and management. However, the prism is a thinking aid rather than a system that can practically be applied. It can be used as a way of thinking to help managers to understand their business context.

Neely and Jarrar (2004) developed the Performance Planning Value chain framework (PPVC). The focus is on what will add real value to the organisation by comparing performance with competitors. Thus, benchmarking was one of the recent methods that has been used in a performance measure evaluation system. PPVC aims to transform data into value-added information that assists organisations in their decisions.

This can be achieved through six steps, including: develop hypothesis, gather data, data analysis and interpretation, inform insights and make decisions. Thus, it is considered as an important input to the organisation's strategy.

However, the focus was on reducing the costs that are required to deliver quick and effective value from data to decision-makers. Following previous traditional measures, PPVC was based only on traditional cost principles. Table 2.2 shows the common performance measurement systems and frameworks applied in the supply chain context.

Table 2.2 – Supply Chain Performance Measurement Systems

Framework/System	**Author**
Performance Measurement Matrix	Keegan et al. (1989)
Time-based competition system	Azzone et al. (1991)
Determinants framework	Fitzgerald et al. (1991)
Balanced scorecard (BSC)	Kaplan and Norton (1992)
Performance Pyramid	Cross and Lynch (1992)
Macro process model	Brown (1996)
Activity-based cost system (ABC)	Kaplan and Cooper (1997)
Performance Prism	Neely et al. (2002)
Performance Planning Value Chain	Neely and Jarrar (2004)
PMS Review	Najmi and Fan (2005)
CCP	Cuthbertson and Piotrowicz (2011)

Huang et al. (2004) classified supply chain performance measurement systems into three groups: operational, design and strategic systems. Figure 2.3 shows that the operational studies developed mathematical models for improving the performance of the supply chain. The design studies aimed to optimise performance through redesigning the supply chain. Different types of models have widely been used in redesigning the supply chain, such as simulation models (Tahar and Hussain, 2000) and stochastic analytical models (Cullinane and Song, 2003). Finally, strategic studies evaluate how to align the supply chain with a firm's strategic objectives.

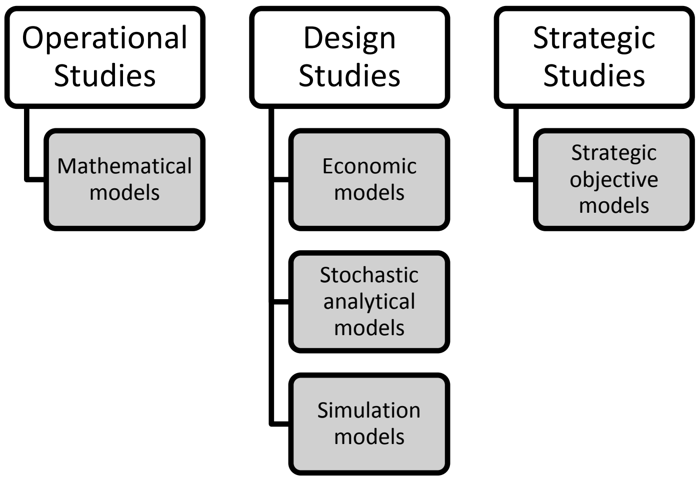


Figure 2.3 – Groups of Supply Chain Measurement Studies

Source: Huang et al., 2004.

Kennerley and Neely (2002) discussed the forces that shape the evolution of the measurement systems. They explained the change of drivers and barriers to change measures within any performance measurement system. Also, a framework of factors affecting the evolution of a measurement system has been developed, including the use, reflect, modify and deploy stages.

Neely et al. (2003) discussed three different generations of performance measurement system. They identified the first generation of measurement systems which are based on financial principles and non-financial indicators, such as Balanced Scorecard (Kaplan and Norton, 1992). They argued that the first generation was static as it did not provide a linkage between performance measures. The second generation of measurement systems addressed the linkage between performance measures. Different measurement frameworks focused on transformations and mapping the flows such as, strategy maps (Kaplan and Norton, 2000).

Neely et al. (2003) claimed that the third generation aimed to link the non-financial and intangible dimensions of business performance to the cash flow in order to subject to the dynamic environment. The main challenges for the third generation are to realise the difference between data and information, to demonstrate the cash flow implication of the non-financial indicators, and to align the models with the organisational processes.

Tangen (2004) claimed that a performance measurement system should be derived from the company's strategy, have diverse types of performance measure, have a limited number of measures to avoid the risk of information overload, be easy to use, have a clear purpose and guard against sub-optimisation. He (2004, p.729) classified performance measurement systems into five categories as follows:

1. Strictly vertical measurement systems where a balance of cost and non-cost performance is considered.
2. Balanced Scorecard measurement systems where several measures are used to match to different perspectives.
3. Frustum measurement systems where low-level measures are used.
4. Measurement systems that are used to distinguish between internal and external performances.
5. Measurement systems that are related to the value chain.

Morgan (2004) argued that a performance measurement system should have five facets, including balance, structure, design, focus and targets. The balance facet refers to use of a range of relevant and relative measures to the organisation. The second facet is about structure, which is derived from the available data and the required activities to be measured.

The design and focus facets are about the importance of the performance measurement system relating to the organisation's strategy. Morgan claimed that the focus should consider the strategic inputs as well as the operational inputs. The target facet is concerning the system's actual ability towards the organisation.

Neely (2005) classified the performance measurement literature into five themes. The first theme presents those studies carried out to identify the problems of the performance measurement systems and to discuss the weaknesses of those systems. The second theme is concerned with developing measurement frameworks to address the identified problems. The third theme aids the measurement framework through providing the ways for populating those frameworks. The fourth theme aims to provide the empirical and theoretical analysis of the performance measurement framework. The fifth theme is concerning the theoretical validity of the empirical investigation.

Franco-Santos et al. (2007) proposed five groups of performance measurement systems according to their roles, including systems used to measure performance, systems used for strategy planning and management, systems used for communication and benchmarking, systems used to influence behaviour, and systems used for providing feedback and improving performance. However, they did not provide the complete list of features, roles and processes for current measurement systems.

Cagnazzo et al. (2010) classified performance measurement systems into five groups, including balanced systems such as Performance Measurement Matrix, Quality systems such as Business Excellence Model, Questionnaire-based systems such as Performance Measurement Questionnaire, Hierarchical systems such as Performance Pyramid, and Support systems and supply chain oriented systems such as Supply Chain Operations Reference (SCOR) model. They categorised measurement systems according to four characteristics that have an impact on the supply chain, including implementation, completeness, objectivity and strategic impacts.

Kurien and Qureshi (2011), based on Cagnazzo et al's (2010) classification, claimed that performance measurement systems should consist of various types of performance measures. They argued that any system should be focused on short-term and long-term results, different types of performance such as cost and quality, various perspectives such as customers and shareholders, and various organisational levels such as local and global performance.

Cuthbertson and Piotrowicz (2011) developed a Content, Context and Process (CCP) framework for analysing supply chain performance measurement systems. The content element includes the categories and dimensions of metrics used in the assessment process. The context element aims to identify the factors that influence supply chain performance; the process element covers the methods and frameworks used to assess the performance of the supply chain. They claimed that the performance measurement literature moved from focusing on single performance measures in the supply chain, to focus on the performance measurement system. They recommended viewing performance measurement as a context-dependent process.

Most studies have stressed the need for new measurement systems and metrics (Neely et al., 1995; Beamon 1999; Beamon and Chen, 2001). New measurement systems need to investigate a number of important issues such as, the factors influencing the successful implementation of a performance measurement system (Bourne et al., 2002), how performance measurement impacts on business performance (Bourne et al., 2005), the factors which shape the performance measurement systems design (Kennerley and Neely, 2002; 2003), examining the relationship between port performance and commodity variety (Ducruet et al., 2010), and using multi-criteria decision making techniques such as fuzzy to design an effective performance measurement system (Valmohammadi and Servati, 2011). A difference between a system, framework and an approach should also be understood. A system has a structure where it comprises elements. Any system has four primary features (Lagoudis et al., 2004):

1. It has a set of interacting elements and components that define a structure.
2. There are relationships between those elements and components.
3. It has a behaviour that is influenced by inputs, processing and output.
4. It has a purpose and a function to achieve.

In the previous part, the literature showed that there are different categories of performance measures, different designs of performance measurement systems, various categories of performance measurement systems and many characteristics of performance measurement. Also, several performance measurement systems and frameworks have been developed for assessing an organisation’s performance within a supply chain context. The next section will look at which supply chain performance measurement systems are currently applied in ports.

2.7 Port Performance Measurement

In ports, using a reliable and efficient performance measurement system provides many benefits for both the port itself and port clients. For a port itself, it helps to understand the functional relationships between key performance variables leading to higher integrated planning and improved port performance. For port clients, it helps to assure the service levels provided, the availability of the required facilities and the reliability of operations. The following section reviews those key performance indicators and performance measurement systems applied in ports.

2.7.1 Key Performance Indicators

The measurement of a port's performance has been approached by researchers in many different ways and by using a range of key performance indicators (KPIs). Some approaches have focused on measuring a port’s performance relative to its performance (Talley, 2007). This approach is called a single-port approach. Studies focusing on measuring port performance relative to the performance of other ports are known as a multi-port approach. Also, some studies considered economic performance as a primary measurement tool in ports. Accordingly, economic performance approaches encouraged other researchers to measure performance in terms of efficiency.

Furthermore, port efficiency has been measured for different purposes. It has been measured with regard to technical efficiency, cost efficiency and productivity. For each measurement approach, different KPIs and measures have been used to meet the measurement purpose.

There are many categories of KPIs that affect port performance, such as proficiency of planning, terminal labour, storage, equipment, type of ship, stowage plan, number of moves per container and labour skills. Out of these, financial metrics have served as a tool for comparing ports and evaluating a port's behaviour over time. Figure 2.4 lists commonly applied categories of KPIs in ports.

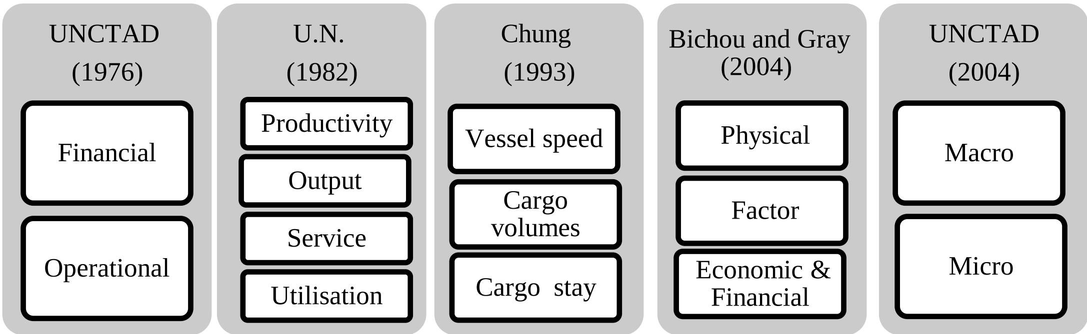


Figure 2.4 – Common KPIs Applied in Ports

UNCTAD (1976) classified performance indicators into two broad categories: financial and operational indicators. It produced a list of factors that affect port performance, which are useful as they assess management efficiency and operational cost-effectiveness. Financial indicators are determined from financial statements, such as the income statement, profit and loss account, and balance sheet. These indicators aim to relate port income and expenditures to total tonnage of cargo handled at the port.

Operational indicators focus on many aspects in ports, such as ship turn-around time, the duration of a ship's stay in port, the volume of cargo, the amount of delay, the average number of calls, average flow-volume or weight-of-goods over a standard period of time, number of calls per berth and per year and volume of cargo handled per call or per day.

The U.N. (1982) categorised the KPIs into four common groups of indicators. These are: productivity, output, service and utilisation indicators. The productivity indicator focuses on total logistics costs in the port, including fixed and variables costs. These costs include port infrastructure, operating cost, inventory cost, and maintenance and repairs costs. Also, costs may include cargo handling equipment, warehouses and labour expenditures. The output indicator measures the outputs of ships, gangs and berths in terms of how many tonnes are handled per hour.

The service indicator takes into consideration the waiting time for ships either in the anchorage area or at berth. Finally, the utilisation indicator determines the utilisation of berths in ports. It calculates the percentage of berth occupancy per month or per year.

UNCTAD (1987) suggested port traffic, berth occupancy and berth throughput as the primary indicators for measuring port performance. It was recommended that measurement should occur on a monthly basis. However, the focus was given to container terminals, with no regard to other types of terminals.

Chung (1993) considered that the speed with which a ship is despatched, the rate at which cargo is handled and the duration that cargo stays in port prior to shipment or post discharge are the main KPIs that should be applied. However, these KPIs are limited to provide how extensively and intensively the port assets are being utilised and how well the operations perform financially.

Valentine and Gray (2002) suggested using other KPIs in evaluating port performance, such as location, infrastructure, and connectivity to other ports. They focused on comparing efficiency between ports in North America and Europe. Total throughput was the output, while the inputs were total length of berth, and container berth length. However, they ignored other activities that influence port performance, such as equipment and storage. Also, these KPIs did not examine the relationship between those variables that influence a port's performance.

Another study attempted to measure the performance of Indian ports by developing a composite index by means of a principal component analysis (De and Ghosh, 2003). This is called the Port Performance Index (PPI), which comprises indicators of operational performance, pre-berthing waiting time, ratio of idle time at berth to time at working berth, asset performance, berth throughput rate, berth occupancy rate and financial performance. The study examined the performance of 12 major ports over a period of 15 years. However, the study considered only those indicators which are directly linked with port productivity. The study ignored other important indicators such as gang output, storage areas, information and other factors outside the port such as transport network and hinterlands.

UNCTAD (2004) categorised port performance indicators into two groups: macro performance indicators and micro performance indicators. The macro indicators work to measure the port's impact on economic activity. They analysed port efficiency as a determinant of trade costs. The micro indicators appraise the input to output ratio measurements of port operations. Nonetheless, the macro indicators seem to focus on the competitiveness of ports as regions rather than ports as firms and micro indicators focus on measuring these operations related to sea access rather than landside port operations, such as warehousing and storage. However, both groups of indicators aim to evaluate the past actions instead of indicating future performance.

Bichou and Gray (2004) argued that it is very difficult to determine what to measure and how to measure it in ports due to dissimilarity between ports or even terminals within a single port. Their study grouped all performance measurement indicators into three broad categories: physical indicators, factor productivity indicators, and economic and financial indicators. The interim port performance model was established, which consisted of four performance measures. The participants in the model included three panels; a ports’ panel, an international institution panel and an academics’ panel.

A combination of questionnaire and interviews were prepared for each panel. It concluded that financial measures were the most commonly used, closely followed by throughput measures for internal performance, whereas productivity and economic impact indicators became more prominent for external comparison with other ports. However, most ports were not satisfied with the current indicators of port performance.

Other KPIs categories have been developed for different purposes. Fourgeaud (2000) divided KPIs into reliability, quality and cost. 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). Talley (2006b) claimed to use operating indicators to assess a port's performance, including loading and discharging rates, channel and berth accessibility, entrance and departure gate reliability and damage to ship and cargoes in port.

It can be concluded that current KPIs focus mainly on cargo handling performance as it is the main activity in ports. Hence, these indicators show the performance level of ports, but they have not found the causes of failure or why port performance is low, nor have they investigated ways to improve the performance. Also, there are many other indicators and functions affecting port performance such as transportation, warehouses, network, and distribution and port clients' satisfaction. These operations have to be measured and considered in a system.

2.7.2 Port Performance Measurement Approaches

The research area in the field of port performance has witnessed a range of theoretical, philosophical and practical frameworks that have been developed for evaluating the performance of ports (Brooks et al., 2010).

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 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 seeks to specify and empirically test the underlying factors that influence port performance and efficiency. These factors are cargo handling, data availability, port size and geographical location, frequency of ships calls, port charges, container mix and terminal efficiency.

The model examined only containerised cargoes across a selected sample of 30 container ports. Port performance was measured in terms of the number of containers moved through a port (throughput). The established model looked at the terminal operation aspect which was measured in terms of the number of containers loaded and unloaded while a ship was at berth. The study concluded that this aspect of terminal operation constituted the largest component of the total ship turn-around time (Tongzon, 1995). To improve efficiency in this area was also consistent with port authorities' intention to maximise berth utilisation.

Tongzon's model was based on multiple linear regression analysis. However, he concluded that some variables such as stevedoring and the crane utilisation rate were incorporated in the model and the equation. He focused on container terminals, with no regard to other terminals and types of cargoes. Also, average inputs have been used instead of actual data, such as average delays, average crane productivity, average government charges and average vessel size.

Notteboom et al. (2000) applied a Bayesian approach based on the estimation of a Stochastic Frontier Analysis (SFA) model. The aim was to evaluate the productive efficiency of 36 European container terminals. The robustness and validity of the estimated model was tested by comparing the results of these to four benchmark terminals in Asia. They concluded that north European container terminals were more efficient. However, the measurement approach was not reliable because the data analysed related only to one year, namely 1994. Also, a Bayesian approach aims to measures a personal degree of belief (data curve) rather than using metrics in the process of performance measurement.

Another study was prepared by Tongzon in 2001. The study applied Data Envelopment Analysis (DEA) to provide an efficiency measurement for four Australian ports and twelve international ports. The DEA analysis was applied based on actual performance data for selected ports. The technique used two output and six input measures of port performance. The outputs were cargo throughput and ship working rate. The inputs were number of berths, cranes and tugs, number of stevedoring labour, the terminal area of the ports and delay times. However, Tongzon's study did not take into consideration other inputs and outputs that affect port performance, such as hinterland, documentation, shifts and security. Also, Tongzon was clearly plagued by poor data availability. His research identified more efficient ports than inefficient ports. Also, statistical tests are not applicable in this technique. DEA does not also measure absolute efficiency and it does not examine the relationship between those variables that influence a port performance.

Estache et al. (2001) measured the efficiency gains of eleven Mexican container ports applying the stochastic production frontier approach- for the period of 1996 - 1999. The main conclusion was that the efficiency has gradually increased and ranking the performance has encouraged competition between these ports.

However, they focused on port competition to stimulate efficiency rather than on measuring port performance itself. The number of workers, the capital used by ports and total volumes handled in ports were the main inputs, ignoring other key factors that influence port competition status, such as storage, equipment efficiency and ship turn-around time.

Valentine and Gray (2001) applied the DEA model to 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. However, their measurement approach failed to show the effects of these relationships in practice.

Itoh (2002) analysed the efficiency changes for eight international container ports in Japan, during the period of 1990-1999. The primary purpose was to determine which port had a high efficiency score. He applied DEA to evaluate the efficiency of a current evaluation system that is called Decision Making Unit (DMU). Labour and infrastructure were the main inputs. However, he focused on measuring the performance of such an evaluation system rather than measuring ports' performance. Also, he did not consider some key variables in ports, such as berth occupancy and ship turn-around time. The focus also was on measuring DMU efficiency in container ports with no regards to other types of cargoes and terminals.

Cullinane and Song (2003) applied the 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. They provided a distinction between productivity and efficiency measurement. However, they focused on measuring the impacts of privatisation, ownership and deregulation on port efficiency, neglecting other key factors, such as the economic environment, political status and investment incentives. Also, the SFA technique cannot estimate technical inefficiency by observation and it is difficult to ascertain precisely the error structure. Furthermore, SFA does not help to examine the relationship between variables that influence a port's performance, nor investigating the impact of these variables on performance.

Wang et al. (2003) analysed container terminal efficiency using two techniques, DEA and Free Disposal Hull (FDH) models. They applied these models to a sample size of 30 container ports. They used throughput as output, and quay length, area, quay crane and yard crane as inputs. However, data concerning labour inputs were unavailable. They focused only on container terminals in ports. Also, they suggested that port efficiency is not significantly influenced by its size, and they considered terminal infrastructure and facilities as key measures. Also, the FDH approach focuses on measuring efficiency as a distance of a particular plan to the dominating production plan (DMU).

Park and De (2004, cited by Choi, 2011) focused on the measurement of productivity, profitability and marketability of eleven Korean ports. They used the congestion and factor efficiency with CCR and BCC models for 2001 data. Berth capacity and cargo handling capacity were the inputs, while cargo throughput, number of ships, and revenue and customer satisfaction were the outputs.

Park and De concluded that DEA is a practical approach to evaluate the overall efficiency of ports. However, they relied on only one year of data. Also, they ignored other key factors, such as equipment utilisation, handling rates, berth length and the number of berths. Also, the CCR and BCC models are only concerned with constant and variable returns to scale (CRS and VRS) that measure the production function when changes in outputs occur when there are changes in inputs. These models don't consider increasing and decreasing returns to scale (IRS and DRS). Additionally, these models are ratio models as they define efficiency as a ratio of weighted outputs over weighted inputs. They compare a producer with only the best producer.

Turner et al. (2004) applied DEA to measure port infrastructure productivity, and used Tobit regression analysis for examining the determinants of port infrastructure. They considered a port infrastructure as a primary performance measure. They included time effects into regressions to clarify that rail service is a critical determinant between ports and the rail industry. However, they focused only on container ports in North America, with no regard to other terminals. Also, they relied on annual TEUs with no distinction between loaded and empty containers, or between 20 or 40 TEUs. They failed to show port managers when they needed to take an action to invest in port infrastructure. In addition, Tobit regression examines the relationship between a latent (unobservable) variable and the independent variables.

Vanags (2004) developed a managerial system for measuring the effectiveness of the port performance at Riga port, Latvia. He used port cargo turnover as an indicator to measure the port performance in relation to five predictors, including territory of the port, the number of berths, the length of berths, the maximum draft of several ships and the total square metres of the warehouses.

The port cargo turnover was used to calculate the performance of three terminals, including container, bulk cargo and liquid terminals. However, he did not distinguish between a dry bulk terminal and a general cargo terminal. Also, he focused on these quantitative indicators that belong to the sea-side leg. The difference between empty and loaded containers was not included.

In 2005, Tongzon and Heng applied SFA to the port industry. Their study investigated the determinants of port competitiveness. Principal Component Analysis (PCA) and a linear regression model were used to examine the effects of key factors on port competitiveness.

Key determinants of port competitiveness include port operation efficiency level, port cargo handling charges, reliability, port selection preferences of carriers and shippers, the depth of the navigation channel, adaptability to the changing market environment, landside accessibility and product differentiation. Two different methods were used to study the determinants of port competitiveness: first, PCA was employed to construct an index of port competitiveness, which was used to justify the total throughput as a proxy for port competitiveness. Then, a regression model of the total throughput examined the determinants of port competitiveness and examined the causal relationship between these determinants and the total throughput.

However, the regression model was based on only one output, TEU’s measurement. The model concluded that the most important factor determining port competitiveness was the adaptability to customer demand. It is argued that the model was very simple as it did not take into consideration any possible correlation structure among random variables. As in previous studies, the model examined only total throughputs in container terminals, regardless of other terminals in ports. It also relied on TEU as a measurement for the output of a container terminal.

Jaffar et al. (2005) investigated performance measures that ports use to enhance their competitive position in the global market. The investigation was in container ports. The performance measure that was used in their model for the container ports was the Twenty Foot Equivalent Unit (TEU).

The port performance predictor variables were: leadership commitment to excellence, modern technology, the efficiency of the terminal, port size and the port hinterland. The model investigated the change in TEU handled over five years starting from 1999 to the end of 2003, using time series analysis. The sample that was used in their study included container ports in the Middle East, Far East and Europe. They concluded and suggested that the most sensitive enablers in affecting the performance of container ports were the port capacity and crane productivity.

Their study however investigated container port performance only, regardless of other types of cargoes. In addition, using TEU reflects only volumes of containers handled in ports, but it does not reflect the performances of other terminals where TEU is not relevant and not in use.

Ng (2005) developed two dynamic programming-based heuristics to solve scheduling problems 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. The focus was on yard crane schedules to minimise the sum of truck waiting time between berths and storage yards. However, he focused on container terminals with no regard to other terminals. Also, he ignored other factors that can influence a terminal turn-around time such as labour skills, drivers skills, the distance between yard and berths, in-port transportation gates and storage capacity and utilisation. These factors can cause delay, bottlenecks and over booking which in turn can affect a terminal's performance.

Barros (2006) applied DEA models. The purpose was to evaluate the performance of 24 Italian seaports for the period of 2002 to 2003. The outputs measured were liquid bulk, solid bulk, number of containers, number of ships, and total receipt, while the inputs were the number of personnel, the capital invested, and the value of operational costs. The conclusion showed that Italian companies displayed good management skills and most of them were Variable Return to Scale (VRS) efficient. However, Barros relied only on a small number of observations. He focused on technical efficiency measurement rather than measuring overall port performance.

Cullinane et al. (2002; 2004; 2006) concluded that the two more appropriate holistic approaches concerning the measurement of port performance are DEA and SFA. DEA has been applied to measure efficiency in 104 European container terminals (Cullinane and Wang, 2006). For the SFA, it is based on using parametric methods of analysis and applied in measuring 36 European container terminals. These approaches have their individual strengths and weaknesses.

The focus however was on measuring container terminals. It ignored many important factors that have effects on port performance, as it depended on cross-sectional and time series data instead of panel data. The cross-sectional data of one year is useful for a particular year but not for multi-period optimisation.

Roh et al. (2007) defined the boundaries of a port cluster system using the 'Structured Analysis and Design Technique' (SADT). SADT is used to provide a robust structured method to model hierarchical systems, and to define and analyse the cluster in terms of the port logistics process. This helped to model the systems that explain how port users and port cluster companies engage in the port logistics process, which consequently affect port performance. Also, it defined those variables that affect a port's performance through breaking down the clusters into seven groups, and defining the components and sub-levels under each group.

SADT did not incorporate a strategic level. Additionally, it is mentioned that SADT includes a construction of multiple models to help in describing a complex system in ports, but it did not explain those models, nor how they can be applied by port managers.

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.

However, these studies aimed only to simulate operational activities in a seaport in order to support decision-makers. From the strategic perspective, these studies failed to simulate other intangible variables such as customer interface, user interface and intangible physical assets.

Tahar and Hussain (2000) used a simulation model, for example, to improve the logistics processes in a port. The importance of their research was that it simulated all the processes required to operate the seaport efficiently and provided detailed statistics on the seaport throughput and utilisation characteristics with a high level of accuracy. The quay cranes allocation, the resource allocations and the scheduling of the different operations were modelled to maximise the performance of the Kelang port in Malaysia. The simulation was carried out using ARENA software. However, their study examined port performance only in terms of crane productivity and berth occupancy in a container terminal. They ignored key factors in ports, such as labour skills, crane scheduling problems and in-port transportation.

Haung et al. (1997, cited by Dragovic et al., 2006) applied queuing models and simulation as primary methods in measuring performance of container terminals. Their study focused on measuring a terminal's performance by classifying berths and ships in terms of length and size using actual data. It helped to explore facilities allocation planning from a systematic perspective. It also provided two scenarios of performance measures through the comparison of the similarities and dissimilarities of the analytical methods and the simulation.

However, the simulation focused only on incoming and outgoing container ships, regardless of other types of ships. Additionally, their study took into consideration three factors; average ship waiting times, average service time and average utilisation of berths. It ignored other essential factors such as gang productivity. Also, the simulation was based mainly on the length of ships, which varies from one ship to another. Thus, it makes the simulation model inaccurate and the findings unreliable.

Goodchild and Daganzo (2007) developed a formula to examine 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. The focus was to determine the number of cycles required to minimise a vessel's time in port. Also, they considered the elapsed time required to move a container from berth into storage areas. In-port transportation and the number of vehicles required were also considered.

They considered double cycling as a main predictor of performance, with no regard to other predictors such as handling rates, volumes and storage utilisation. They ignored other types of cargo as they focused only on containers. Moreover, they failed to take into consideration that some containers are directly shipped to the domestic market whilst others are transhipped. They assumed that all containers are shipped for one purpose. Accordingly, they failed also to consider which containers should be directed to which storage cell regarding its destination. They relied on operational simplicity in developing their formula for improving a ship's output and loading plan, while they ignored key factors, such as berth occupancy.

Bichou (2007) argued that current measurement approaches are incompatible with the port industry. Based on a benchmarking purpose, three broad categories of performance measurement were established, including individual metrics, economic impacts studies and frontier approaches. He claimed that few approaches have linked and integrated operations, design and strategy with port functions. He developed an integrated supply chain framework for port performance benchmarking. Two methodologies were applied, including selecting relevant performance metrics and designing a system, and benchmarking against a group of ports.

Barros and Managi (2008) examined the technical efficiency of Japanese ports from 2003 to 2005 through two stages. In the first stage, they applied DEA to rank ports according to their efficiency. In the second stage, the Simar and Wilson (2007) procedure is applied to analyse dependency between the efficiency scores and other variables in ports. The number of personnel and number of cranes were the main inputs, while the number of ships, tonnes of bulk and number of TEUs were the main outputs.

However, they assumed that all ports use the same technology for transforming inputs and ignored many key variables in ports, such as handling rates and storage. Also, the Simar and Wilson (2007) procedure applies a data generating process (DGP) which is used to convey a number of different ideas (latent variables) rather than real variables that influence a port's performance.

Liang and Rong (2008) applied a probability distribution of cargo throughputs determined by time spent by a ship in port. They applied the Wald equation, which is based on the relationship between time required by a ship in port and the operational capacity of handling equipment at the port. However, they failed to examine if their model can measure a port's performance and they ignored other factors such as clearance time and storage availability. Also, the Wald equation is only used to calculate the expected value of the sum of a random number of random quantities. It does not examine the impact of variables such as a ship's time in port on port performance.

Gonzalez and Trujillo (2009) grouped measurement approaches for port efficiency into three groups. The first group comprised the partial productivity indicators. The second group included engineering approaches such as queuing theories, while the third group involved the technical frontier techniques. They argued that an efficiency concept is directly derived from productivity. However, they focused on efficiency, with no regard to an effectiveness dimension in a port. Also, they focused on measuring a port's performance in terms of port technology, with no clear methodology as they combined SFA and DEA techniques.

Sharma and Yu (2010) claimed that the traditional DEA approach was not helpful in ranking Decision Making Units (DMUs) based on their relative degrees of efficiency and inefficiency, nor did it identify those variables that have great impacts on efficiency. Hence, they applied the decision tree approach based-DEA on 70 container terminals. Six inputs were used, including quay length, terminal area, quay cranes, transfer cranes, reach stackers and straddle carriers.

They concluded that terminals with high attractiveness scores have less threats and are therefore highly attractive, and vice versa. However, a decision tree approach helps to identify a strategy to reach a goal rather than measuring a performance and it is limited to one output.

Ducruet et al. (2010) applied a multiple regression analysis, Ordinary Least Square (OLS), to examine the relationship between commodity variety and port performance. A commodity diversity index was the response variable and the predictors were divided into three groups including: port performance predictors, such as, total traffic; geographical predictors such as, latitude; and regional economic predictors such as, the labour market. Significant variables were only considered in their model and multicollinearity was tested. They concluded that there is a strong impact of demographic size, traffic balance, accessibility to and distance from main economic cities and position in maritime networks on port performance.

Simoes and Marques (2010) divided port performance measurement techniques into three groups. The first group comprised those techniques that use performance indicators. In the second group, parametric efficiency techniques were applied, such as SFA. Non-parametric measures were used in the third group, such as DEA and FDH. They measured the performance of 41 ports in 11 European countries using a robust bootstrap approach. They concluded that ports can save 22 % of their costs if they are operated in an optimal way. However, the data analysed was related to the single year of 2005. This makes the measurement approach unreliable.

Additionally, a bootstrapping approach can only be used when a sample size is not sufficient through repeating a computation of a mean for each sample many times to provide a histogram of the bootstrap sample. It does not consider those variables that influence a port's performance and it has always a tendency to be optimistic.

Zouari and Khayech (2011) argued that port performance can be assessed using a three-dimensional measure method that is known as ‘Cost-Quality-Delay’ method. The method aims to reduce total costs of cargo stopovers, to improve the service levels and to lower delays of cargo and ships at ports. Also, they discussed six dimensions of port performance, namely commercial, operational, financial, organisational, social and citizen dimensions. However, they focused only on commercial and operational performance of Sousse port, Tunisia, with no regards to other dimensions. They measured the commercial performance using the number of calls and total tonnes handled, and they measured the operational performance using the average time of stopovers that includes waiting time.

Taneja et al. (2012) discussed the incorporation of flexibility measures in port infrastructure design. They argued that this measure provides a port with a plan to cope with a changing environment and uncertainty. They recommended using financial techniques such as discounted cash flow analysis (DCF), return on assets (ROA) and enterprise risk management (ERM). A three-layer infrastructure model (inframodel) was developed to provide flexible options to port planners and decision makers. However, they did not show how flexibility measures can be calculated in a port, nor how it can be applied in reality. The inframodel was developed to help planners rather than operators.

Dorsser et al. (2012) investigated port performance through forecasting the port throughput. They developed a very long term forecast of the Le Havre-Hamburg region throughput up to 2100. They argued that this forecast will help infrastructure planners to consider suitable capacity in the future. The port throughput was the response and the economic activity measured in GDP was the predictor.

Regression analysis was applied to examine the relationship between the port throughput and GDP. The results showed that r-squared was 95%. However, they did not consider other factors that influence a port's performance rather than port throughput, such as a number of calls, equipment efficiency and availability, number of working hours and the port infrastructure. Table 2.3 summarises these common approaches that have been developed for assessing ports' performances.

Table 2.3 – Performance Measurement Approaches Applied in Ports

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

2004	Park and De	BCC, CCR	Throughputs	One year of data
2005	Tongzon and Heng	SFA, Liner Regressions	TEU's measurement	Simple model
2005	Jaffar et al.	TEU	Containerised ports	Irrelevant parameter
2006	Roh et al.	SADT	Efficiency	Port users focus
2007	Bichou	Panel Survey	Benchmarking	Container port focus
2008	Barros and Managi	DEA	Port efficiency	Missing key variables
2009	Gonzalez and Trujillo	SFA and DEA	Efficiency	No clear methodology
2010	Sharma and Yu	Decision-tree Approach	Terminal attractiveness	Container terminal
2011	Zouari and Khayech	'Cost-Quality-Delay' method	Logistical port performance	Commercial and operational focus
2012	Taneja et al.	inframodel	Port flexibility	Theoretical model
2012	Dorsser et al.	Regression analysis	Port throughput	Ignoring other factors

Appendix A displays these frameworks and the measures in the literature for evaluating ports' performances. It shows that some studies focused on developing frontier methods using non-parametric techniques such as DEA to understand and measure port efficiency, while other studies used parametric techniques such as the Bayesian technique. These studies concluded that a port's operational efficiency level does not depend solely on its size or its function. Other measures were applied, including financial, production, efficiency, time, cost, profit, effectiveness, technical and economic measures.

Developing a more-effective performance measurement system is required to assist in improving port performance. The main difference between a more effective performance measurement system and current systems is that the effective system should rely on KPIs that are derived from a port's objectives. It should be a management tool, an improvement tool, as well as a measurement tool.

2.8 Limitations of Current Measurement Systems

As discussed earlier, it is obvious that most of the previous research in this field of study applied different performance measures and used various techniques. Hence, no unique measurement system has been recommended for ports. Each port applies different KPIs and analyses various measures. The following reasons explain why current port measurement approaches are inconsistent and unsatisfactory:

1. Current measures and KPIs focus on measuring productivity issues rather than measuring performance such as productivity of port facilities (Turner et al., 2004), berth capacity and cargo handling capacity (Park and DE, 2004), TEU (Jaffar et al, 2005) and crane double cycling (Goodchild and Daganzo, 2007). Current systems aim to maximise productivity through maximising outputs or through minimising inputs for given outputs. For this reason, different measures have been developed using different techniques, including berth allocation models, landside gate operations and crane efficiency.

2. 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). These systems focused on terminal operations rather than port operations, and most focused on measuring sub-activity of the terminal process, such as yard productivity. Hence, current measurement systems in ports are limited, as not all terminals are included in these systems.

3. Current measurement systems lack a strategic focus (Neely et al., 1995; Bourne et al., 2000). The focus is often more towards improving terminal productivity rather than improving port performance. Thus, most current systems partially fit a port's strategy and objectives. The focus was on linking the capacity with the terminal operation company’s strategy. Shepherd and Gunter (2006) argued that current performance measurement systems lack the connection with strategy.

4. 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 costs (Sanchez et al., 2003). As discussed earlier, different measurement categories should be considered such as quality, flexibility and time. These categories need to be considered to provide a reliable system.

5. Most measurement systems are not applicable in practice, or managers have not indicated how to apply these in reality. Bichou and Gray (2004) based on 45 respondent ports to their questionnaire concluded that most ports are not satisfied with current measurement techniques and face difficulty in applying and understanding these techniques.

6. Measuring the efficiency side is the main focus in the current systems (Brooks and Cullinane, 2007; Brooks et al., 2010; Pallis et al., 2011; Brooks et al., 2011). There was clearly no regard towards the effectiveness side. Little research has mentioned the importance of land-side efficiency such as hinterlands, regardless of how it can be measured.

7. Measuring containerised cargoes, container port and container terminals are the objectives of most current systems in the last 10 years (Brooks et al., 2011). This makes current systems inconsistent. A port has many terminals and handles normally more than one type of cargo; dry bulk, liquid bulk, LNG, general cargo, for example. A focus on measuring one type of cargo does not reflect a port's performance (Pallis et al., 2011).

8. 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. The purpose of this research is to build new equations and to construct new measures. Current techniques discussed in the literature such as DEA can be used to analyse existing measures and are useful for different purposes.
9. The majority of studies discussed how to relate the performance measures to the strategy of ports. However, these studies did not explain how to relate the

performance measures with the ports' objectives and the qualities that are needed to deliver their strategies.

10. Some key performance variables have been ignored that have great influence on port performance. These variables should be considered when measuring port performance, such as standing time, total time cargo remains in the port and clearance time.
11. Most measurement systems focused on assessing historical performance rather than future performance. These systems were designed for external reporting rather than managing the business enterprises (Bourne et al., 2000).

2.9 Chapter Summary

For supply chain performance measurement, the literature showed that performance measurement system is a set of metrics used to assess the efficiency and effectiveness of actions. Cost is a traditional accounting approach to performance measurement which is no longer appropriate as the sole criteria for assessment (Kennerley and Neely, 2002). A range of characteristics have been used for categorising performance measures. In port studies, current key performance indicators (KPIs) are incomplete measures of performance. **There is a need to develop a more efficient analytical framework that could be used for measuring port performance.** Most port studies disaggregate factors such as standing time and focus on single, or a small number of, port operations. Port managers claim that the current measurement systems are unclear and inadequate and difficult to apply in practice. Also, a focus on measuring containerised cargo was the main purpose in current frameworks and approaches. The literature showed that no model has been recommended as a valid tool for performance measurement in all ports. Pallis et al. (2011) claimed that sub-topics in port studies need more investigation and development such as dwell times and related charging policies, using further methodological approaches. This research aims to develop a more effective measurement system as it helps ports to be more proactive in value-driven supply chain systems through considering those variables that influence a port's performance for all types of handled cargoes. Examining the relationship between these variables and a port performance will be carried out. The next part, Chapter Three, will discuss the research philosophy, methodology, strategy and process toward designing a port performance measurement system.

Chapter Three

Research Methodology

3.1 Introduction

Port managers need reliable and accurate information to make informed decisions to successfully deal with their complex daily operations. The information provided by the port managers and authorities for the purpose of measuring their port performance could be the result of a careful analysis of data gathered or of data that are already available. There are several types of data that should be collected and analysed. This is because there are different terminals that handle different types of cargoes, and different operations, activities and services that are provided in ports. The robustness of the analysis depends very much on the quality of data used.

Data should be collected for those predictor variables and operations that influence port performance. It helps to understand how performance can be improved through identifying the weaknesses in aspects of the operations. There is a need to understand the problem of optimising the time for loading and unloading cargoes to and from a ship at a terminal, waiting time, total time a ship stays in port and clearance time. This chapter aims to understand and present the key layers of the research, including

1. The research questions;
2. The research philosophy;
3. The research strategy;
4. The research process;
5. The data collection methods; and
6. The sample size and type of data

3.2 Research Questions

The research examines different measurement techniques applied in assessing supply chain performance. Following this, the research questions have been generated and selected accordingly concerning measurement techniques applied in ports and their effectiveness. The answer to these investigations and more specific questions helps to satisfactorily arrive at a conclusion about the research aims.

Findings from the literature review considered that current measures are limited as they only focus on measuring efficiency in containerised cargo and lack the focus on port strategy. Hence, the aim is to develop a more effective performance measurement system of operations at a port. There is a variety of inputs, outputs, internal factors and external factors that influence port performance. This multiplicity requires selecting properly those variables that affect a port's performance. The research has set the following hypothesis to provide a more effective system for those decision makers in seaports:

Developing a more effective performance measurement system will lead to improved performance in Damietta port

This hypothesis statement can be divided into several investigative research questions:

1. What is the measurement system that is currently applied in measuring port performance?
2. Are measurement systems currently applied in ports effective?
3. How can measurement system be developed to measure port performance?
4. What are the relative and relevant variables that influence a port's performance that have not been considered in current models?
5. What is the significance of the relationship between these variables?

The answer to these questions requires a case study as an in-depth investigative technique. Damietta port is selected as a case study as it helps to understand those inputs, outputs, internal factors and external factors that influence a port's performance.

In a deductive method, it is required for a hypothesis to be falsifiable (Sekaran and Bougie, 2010). This explains why a null hypothesis is accompanied and seemed to be true until statistical evidence proves otherwise. In this research, a null hypothesis (H_N) states that developing a more effective performance measurement system will not lead to improved performance in Damietta port. However, a null hypothesis cannot be tested definitively (Cooper and Schindler, 2003). Hence, possible rejection of a null hypothesis using statistical evidence supports an alternative hypothesis (Sekaran and Bougie, 2010). The alternative hypothesis is the logical opposite of the null hypothesis (Cooper and Schindler, 2003). In this research, the alternative hypothesis (H_A) states that developing a more effective performance measurement system will lead to improved performance in Damietta port.

3.3 Research Philosophy

The research is deductive and it works from the more general to the more specific, which is known as a top-down approach. It starts by investigating measurement systems in a supply chain context before narrowing these down into these systems applied in ports. A deductive approach aims to design a strategy to test a hypothesis and is positivist in nature. Positivism reflects the research philosophy that implies observable reality and where quantifiable observations lend themselves to statistical analysis (Saunders et al., 2003).

A deductive methodology enabled an involvement in the port working environment, with enhanced data collection processes, sampling size, data type, data preparation, timing, data analysis and level of data security. Also, a quantitative study helps to interpret collected data and to represent the conclusions. Thereafter, interviews with the port managers and directors have been considered to verify the accuracy and reliability of data and to identify their needs in terms of a performance measurement system. A detailed description of port operations helped to develop a detailed understanding of the predictor variables that influence a port’s performance.

The deductive-positivism philosophy is linked with the development of knowledge and has several characteristics. Firstly, it helps to explain causal relationships between those variables that influence a port's performance. Secondly, it allows the testing of the hypothesis and the collection of quantitative data. Thirdly, concepts can be operationalised in a way that enables facts to be quantitatively measured (Saunders et al., 2003).

Maylor and Blackmon (2005) discussed that any research philosophy has ontology which is concerning the nature of reality, and it can be objectivist ontology or subjectivist ontology. In this research, the philosophy is going to be more objectivist ontology, where an explanation of the behaviour of predictors over port performance will be conducted. Objectivist ontology deals with what is physically real, with no regards to the social objects, and where the results are based on the facts of the findings derived from actual data (Sekaran, 2003).

Another alternative approach is an inductive approach for measuring port performance. It follows a bottom-up approach that helps to move from specific observations to a broader generalisation. Hence, inductive, by its nature, is more open-ended and exploratory, while deductive is narrower in nature and is concerned with testing hypotheses (Sachdeva, 2009). Sachdeva (2009) argued that a first step in the exploratory study is to start with reviewing literature studies as it is inefficient to discover a new issue through a collection of primary data.

Using the inductive approach, a port performance can be measured using customer satisfaction and customer loyalty (Pallis and Vitsounes, 2008), port strategy (Brooks and Baltazar, 2001), port privatisation (Baird, 2000), port policy and regulation (Notteboom, 2002) and port related employment (Musso et al, 2000). However, the inductive approach is not suitable in this research for the following reasons:

- It takes a limited amount of observations to provide a universal conclusion which could be still false.
- It is difficult to get reliable and accurate data about social objects and human behaviours in the Egyptian ports.
- Confidentiality is a main problem in obtaining information.
- Some qualitative measures are uncontrollable such as loyalty (Pallis and Vitsounes, 2008).

3.4 Research Strategy

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’, ‘what’ and ‘why’ questions through providing a rich understanding of the real environment (Saunders et al., 2003). Sekaran and Bougie (2010) argued that a case study that is qualitative in nature can help to understand certain phenomena and can be used for empirical testing. Hence, Damietta port is used as a case study as data was readily available to comprehend how variables can affect port performance.

3.4.1 A Case Study of Damietta Port

Damietta port has been selected as a case study as it is an information-oriented sample. The theoretical concept of using a case study is to help define the unit of analysis, to determine the feasibility of the research process, to identify the relevant variables and cause and effect relationship, and consequently data to be collected as part of the case study (Yin, 2003). The reasons of choosing Damietta port above other Egyptian ports are:

1- Damietta port is a multi-purpose port, where there are multiple terminals and it handles various types of cargoes. This helps to develop a measurement system for various types of cargo rather than focusing on containerised cargo.
2- The port is connected by many modes of transport (railway, road and river). The port is designed to handle high capacities that are not available in other ports in Egypt. Thus, the port's productivity can be maximised to meet any increase in demand in the future.
3- The port is close to the Suez Canal and consequently to the international shipping routes. This means that demand can be potentially generated if the port performance is improving.
4- Damietta is one of the three hub ports in Egypt. The other Egyptian hub ports are East Port Said Port and West Port Said Port.

5- Damietta port is one of 15 commercial ports owned and operated by the Egyptian government. This helps to understand the similarity in operations, management and current measures applied in other ports.
6- There are similar elements between Damietta port and other Egyptian ports such as Alexandria port and East Port Said port namely physical infrastructure, technological infrastructure, type of available data, corporate strategy set by the Ministry of Transport, performance measures and KPIs applied, managerial hierarchy and financial structure. This helps to apply the developed model (DAPEMS) in other ports in the future with modifying the regression equations.
7- In 2010, Damietta port was ranked 90th in the world in terms of container traffic. By 2011, the port's ranking had moved up to 53rd place. There is a need to understand the factors which influenced the improvement in this ranking.

3.4.2 Objectives of Using a Case Study Method

The case study method will:

1. Provide analysis of operations in Damietta port.
2. Help to explain why port performance can be influenced.
3. Narrow down very broad operations in ports into a more easily researchable topic.
4. Test whether the developed DAPEMS model actually works in practice.
5. Provide more realistic responses than a purely statistical survey.

The usefulness of using a case study method is to examine the effectiveness of the current measurement approach applied in Damietta port. This will be further detailed in Chapter Four.

3.4.3 The Case Study Type

There are different types of case studies. For this research, it was essential to select an explanatory and instrumental case study. The explanatory case study assisted the causal investigations between key variables in ports, while, the case is instrumental as it was used to understand more than what was obvious to the researcher through investigating the influential behaviour of predictors on the performance (Stake, 1995). 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 techniques, such as regression analysis.

In addition, Yin (2009) argued that the type of the case study should be selected according to the type of research question. He argued that a 'how' question, as in the case of this research (see Section 1.5), is more explanatory and it requires the use of a case study. The justification is that the question 'how' deals with operational links and it requires in-depth investigation (Valmohammadi and Servati, 2011).

On the other hand, the case study can be a single-case or a multiple-case application. In this research, a single-case of Damietta port was conducted. In Egypt, the operating environments at ports are similar as they are owned and operated by the government. Hence, a single-case is a typical system of action that represents similar operations in other Egyptian ports. Similarity exists in the managerial hierarchy, operational strategy, technological and financial structures, and type of available data.

There is frequent criticism of using single-case study research in that the results are not widely applicable because it may be a small sample. However, a single-case study tends to be sufficient to present a well constructed explanation of current performance, to understand the effectiveness of the current performance system being examined, and to implement a proposed system.

The reasons for using a single case study are as follows:

- A single case can be used as a template against which to compare the empirical results of the case study.
- Yin (2009) argued that a single case study can represent a significant contribution to knowledge as it is assumed to be informative in the situation where there is similarity between organisations. Consideration must be given to test the reliability of using a case study.
- The protocol for carrying out the data collection from a single case is considered as a major way to test the case reliability (Yin, 2009). The explanatory-instrumental single case study will indicate which port will be analysed, the roles of people to be interviewed, where interviews will be carried out, what data are requested and in which form, what documents and records are needed and how data can be gathered.
- Generalisation can be made as a single-case can be formal case protocol in terms of procedures and steps.
- Gillham (2010) argued that a single case can provide a powerful argument as it does not set a limit on what people can achieve.
- A single-case study was easier to visit and collect data. Atkins and Sampson (2002) argued that a single case provides in-depth investigation and rich description rather than spending time in cross-cases comparison.
- A single case study can be relevant if a case seems to represent a critical test to existing theory (Yin, 2009)

3.4.4 Designing the Case Study

The design of the explanatory-instrumental case study has considered five elements (Yin, 2009):

1. The research problem.
2. The choice of the case study.
3. Data collection methods.
4. Units of analysis.
5. The criteria for interpreting the findings.

(1)The research problem is to determine how current performance measurement systems can be developed to measure the performance of ports. (2) A single case study can provide a detailed understanding of current problems and the working environment. (3) Different methods have been applied for collecting data. These methods are: interviewing, port records, governmental records and observation during port visits. The purpose is to collect relevant information about key factors in the port. (4) Damietta port has been used as the unit of analysis to investigate both the key variables influencing the port's performance, and the significance of the relationships between these variables and how they can affect the overall performance. (5) The criteria for interpreting the findings was testing the reliability and applicability of DAPEMS for measuring port performance using multiple regression analysis.

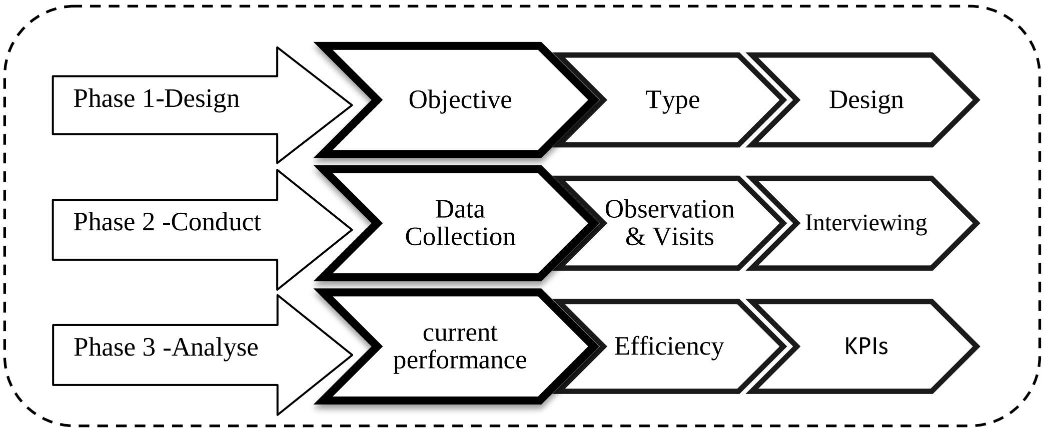


Figure 3.1 – Phases of Applying the Case Study

Figure 3.1 shows the different phases of applying the case study in this research. Phase one involved three components. Firstly, it deals with the purpose of using the case study in this research. It also explains what type of case study has been used and it finally explains the five components of the case study design. This has been discussed earlier in this Chapter.Phase two is the conducting of the case study. There are three interrelated tasks in this phase. In this phase, the main component is the preparation of the data collection. The methods of data collection are considered critical to enhance the reliability and applicability of DAPEMS.

As discussed earlier, multiple sources of data have been considered in the case of Damietta port. The second phase is concerned with discussing the types of data collection sources applied in Damietta port, which takes place in Chapter Four. Phase three deals with the evaluation of data collected in Damietta port using regression analysis. Simple regression models have been established to test the correlation and relationship between key variables in the port. Then, multiple regression models have been established to find the best fit models that can estimate port performance. Data analysis has been applied to four types of cargoes: general cargos, containers, dry bulk and liquid bulk. A series of statistical tests have been applied to help in presenting, discussing and examining the effectiveness of the regression models, such as testing multicollinearity, scatter plots and probability plots. All analyses were carried out using MINITAB statistical software version 15 and Excel 2007. This phase takes place in Chapter Five.

3.4.5 Regression Analysis

Different techniques were widely applied in the literature for the purpose of measuring port performance such as DEA, SFA, Bayesian approach and decision tree approach. However, the Ordinary Least Square (OLS) regression is used for data analysis in this research for the following reasons:

1- Examining the relationship between those predictors that influence port performance, the strength of the relationship, and the direction of the relationship.
2- As discussed in Chapter Two, traditional performance measurement systems provide little indication of future performance (Kennerley and Neely, 2003) and new frameworks should focus on future performance measurement (Bourne et al., 2000). Regression analysis can be used in prediction for future performance.

3- OLS minimises the sum of the squared errors (SSR), provides optimal linear unbiased estimation when errors are uncorrelated and when predictors have no multicollinearity, provides the maximum likelihood estimator when errors are normally distributed, can easily be used by port managers, can be expressed by a simple formula and handles the noise of statistics in the dependent variable.
4- Techniques other than regression analysis do not fully examine the relationship between a port's performance and the variables affecting that performance. They can be used for different purposes rather than the purposes mentioned in this research.

The purpose of this research is to develop a port performance measurement system that predicts future performance rather than assessing historical performance. This is to meet the port manager's needs as discussed in the interviews (see Appendix H) for the following reasons:

- To predict future demand on port services. This, in turn, will help port managers to cope with changes in traffic and volume demand.
- Predicting future demand helps to set a future investment plan.
- Damietta port is owned and operated by the Egyptian government. Any expansion in the port facilities requires enough time to receive a budget from the Ministry of Transport.
- Predicting future performance and bottlenecks enables proactive management of the port infrastructure.
- Analysing historical data is used for external reporting rather than assessing actual port performance.
- Predicting future performance enables management to change operational techniques at the right time in order to reap the greatest benefit.
- It helps management prevent losses by making the proper decisions based on predicted information.

This also justifies why regression analysis was applied in this research. The following statements summarise the assumptions of OLS regressions applied in this research (Stephens, 2004):

1. The starting point is the regression equations which describe the causal effects.
2. It is assumed that the errors have an expected value of zero. This means that the errors are balanced out.
3. It is assumed that the independent variables are non-random.
4. It is assumed that the independent variables are linearly independent. That is, no independent variable can be expressed as a non-zero linear combination of the remaining independent variables. The failure of this assumption is known as *multicollinearity*.
5. It is assumed that the disturbances are homoscedastic. This means that the variance of the disturbance is the same for each observation.
6. It is assumed that the disturbances are not auto-correlated. This means that disturbances associated with different observations are uncorrelated.
7. The error terms are normally distributed.

Given the above assumptions, OLS regression is the Best Linear Unbiased Estimator (BLUE) principle (Wooldridge, 2005). This means that out of all possible linear unbiased estimators, OLS provides the precise estimate of the response.

Regression analysis has been chosen in this research to develop a performance measurement system. This helped to investigate the dependences between different measures. This can be achieved using regression analysis rather than discussing the correlation between variables.

Correlation and regressions are not the same as correlation quantifies the degree to which two variables are related and it does not find a best-fit line. A correlation coefficient can only indicate how much one variable tends to change when the other one does. Regression determines how the response variable changes as a predictor variable changes and it can predict the value of the response variable for any predictor variable.

3.5 Research Process

The purpose of this research as stated in Chapter One is to develop a port performance measurement system. Accordingly, the research is an explanatory study that explains the relationships between variables and establishes causal relationships between these variables.

A performance measurement system is a managerial task where a required system should support the port in its current functions in a consistent way (Morgan, 2004). Neely (2004b) argued that the main challenges for performance measurement systems are the design, implementation, managing and refreshing of the measurement systems. He focused on selecting the right measures for proper system design. The implementation stage is influenced by both accessing accurate and reliable data, and a consideration of political and cultural issues.

However, selecting the right measures for proper system design firstly requires defining the strategic objectives (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 organisation, the next step is to design a system through selecting those 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).

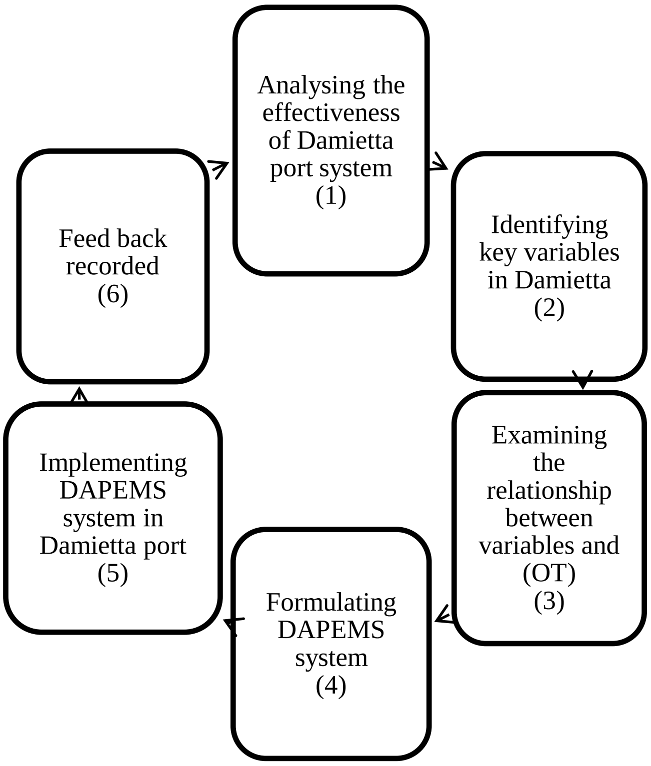


Figure 3.2 - The Research Processes

The literature review helped to conceptualise the research process as shown in Figure 3.2. The research process begins with defining the current performance measurement system applied in Damietta port. The first stage of the process is to analyse the effectiveness of the current Damietta measurement system and the measures currently in use within the current system.

It helps to handle a more customised approach of measures and indicators used to monitor port performance, forecast development and targets in the port sector. The purpose is to verify the reliability and adequacy of current measures. This helps also to determine whether re-engineering for the current performance measures is needed or not.

The second process aims to identify the measures that influence Damietta port performance. This is due to the inadequacy and inconsistency of current measures, as discussed in Chapter Four. Braz et al. (2011) argued that existing measures are rarely deleted, and adding new measures to existing measures leads to an increase in the system's complexity.

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 third research process will examine the relationship between these variables and port performance. Those variables and measures that have no relationships are not considered as part of a measurement system. Examining the relationship between performance measures helps to determine the measurement framework and the way in which the system will measure port performance.

In the fourth process, developing a more effective measurement system has taken place using three measurement categories: time, revenue and flexibility. The research will implement the proposed system as the fifth process. Implementation is a necessary process to verify that a system meets managers' expectations (Braz et al., 2011). It also helps to examine the reliability and applicability of DAPEMS. The last element of the research process is to summarise the feedback from the port managers at Damietta port (Chapter Seven).

3.6 Research Methods

The use of appropriate methods greatly enhanced the value of this research. Data have been obtained from primary and secondary sources. Primary data focused on obtaining information about key variables that influence Damietta port's performance. Secondary sources helped to identify those supply chain performance measurement approaches that are currently applied in ports.

3.6.1 Data Collection Methods

Various data collection methods have been applied for gathering data and information about performance measurement systems in the supply chain context in ports and in the operating environment of Damietta port. Also, a mass of information has been collected through multiple techniques for each key performance variable used in the DAPEMS. Figure 3.3 shows the overall data collection techniques applied in this research and the multiple data sources used.

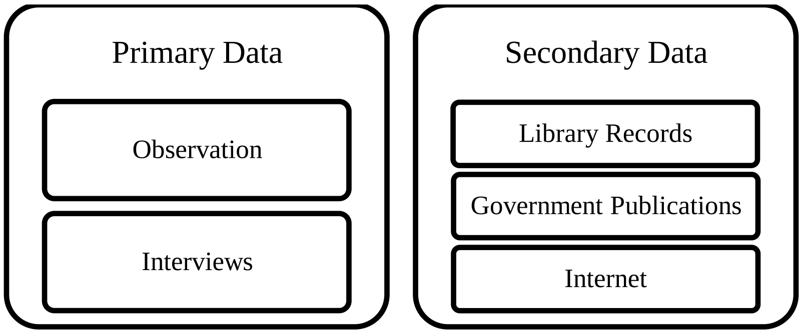


Figure 3.3- Overall Data Collection Methods

Selecting information and data sources was based on a source evaluation principle. The principle was based on three factors that were applied by the researcher. These are:

1. Purpose – the purpose of the source is essential to determine whether and how the source provides a bias to the presented information. It shows what the source is trying to present and discuss. Understanding the purpose of the source made the search process easier as it helped the researcher to verify the usefulness of the source.
2. Scope – the scope of any source of data is coupled closely to the purpose. It was important to determine how much of the topic is covered and to what depth? What time period do these sources cover? And what is the date of publication.
3. Format – it was important to determine how the information is presented and how easy it was to find a specific piece of information.

3.6.2 Primary Data Collection Methods

A. Observation

It is a technique that involves systematically selecting, watching and recording behaviour and characteristics of Damietta port performance during port visits. Observations provided additional and more accurate information on the behaviour of Damietta port performance than interviews or questionnaires. It helped to check on the information collected through interviews (Robson, 2011).

Thirteen visits were conducted between August 2007 and June 2011. Each visit took up to two days for observing port operations such as cargo loading and discharging at different terminals, berth occupancy, storage yards and warehouses, the traffic control bridge, logistics centre, in-port transportation and waiting time at berths. All the observations have been recorded manually by the researcher. Conducting observation was useful because:

1. It is one of the most direct research techniques.
2. It is used in combination with interviews. Hence, observation could therefore provide useful insights into the extent to which there is a correlation or discrepancy between what port managers say and what they actually do.
3. Observing Damietta port operations provided better and direct information.
4. It helped to understand the port managers' characteristics.
5. It allowed the researcher to describe the full complexity of the situation.
6. It helped to identify certain observed problems, such as cargo remaining for a long time at a certain terminal.

B. Interviewing

Unstructured, structured and telephone interviews were conducted to obtain information about the operating environment and to explain the cause-and-effect relationship between key variables in Damietta port. Appendix H shows a sample of the interviews conducted at Damietta port. This sample is incorporated into this research to explore the beneficial information obtained from the port's managers and to show how these interviews helped to understand their needs. Also, they helped to explore those external factors that cause poor performance.

Unstructured interviews aimed to identify some preliminary issues to determine which variables affect port performance and consequently which required further in-depth investigation. Interviewing the port director required unstructured interviews where there are no specific questions, nor order of topic to be discussed. After conducting unstructured interviews, there was a need to identify the variables that need greater focus and call for more in-depth information.

This required structured interviews with managers at several levels. Conducting unstructured interviews were beneficial because:

- It made interviewees more relaxed to present ideas.
- It permits full exploration of ideas and beliefs.
- It gives maximum flexibility to be to pursue questioning in whatever direction appears to be appropriate.

Structured interviews with the port personnel followed. Questions focused on those key variables that had surfaced during the unstructured interviews. Interviews involved oral questioning of respondents, and answers to the questions posed during an interview were recorded. Visual aids such as port maps and annual reports used to explain the important factors influencing port performance. conducting structured interviews were beneficial because:

- It allows for a wide topic area to be looked at.
- Quick and cost effective to get directly needed information.
- It allows for easy data analysis.

Managers at several levels were interviewed including the port director, operations manager, logistics manager, technical office manager, public relations manager and operation supervisors. The port director was firstly contacted to explain the purpose of this research and to get permission for conducting interviews with the port managers and employees. Also, he helped to select the interviewees. This was useful to avoid any unwillingness or inability of the interviewees to participate, to keep interviewees motivated to respond and to provide reliable information and to restrict bias. Table 3.1 details the interviews that were held at the port managers' offices at Damietta port:

Table 3.1- Interviews Conducted at Damietta Port

Date	Place	Interviewee
21-08-2007	Damietta port	Port director Operations manager Traffic manager
12-02-2008	Damietta port	Manager of public relations Operations manager Traffic manager
26-06-2008	Damietta port	Workers and staff
23-12-2008	Damietta port	Traffic manager Operations manager Engineering affairs manager
02-02-2009	Damietta port	Port director Technical office manager
05-02-2009	Damietta port	Technical office manager Manager of public relations
07-10-2009	Damietta port	Logistics manager Operations manager
18-03-2010	Damietta port	Operations manager Traffic manager
26-05-2010	Damietta port	Port director
29-11-2010	Damietta port	Operations manager Technical office manager Manager of public relations
12-01-2011	Damietta port	Technical office manager
20-04-2011	Damietta port	Operations manager
18-06-2011	Damietta port	Operations manager

Conducting interviews was useful because:

1. It provided an opportunity for the interviewee to give more detailed information.
2. The statistical data became richer and fuller with contextual information.
3. The data have been collected in a natural setting.
4. An interview was a particularly useful tool to understand the experiences and actions of each individual respondent.
5. It provided an opportunity to explore respondents' views.
6. It provided the researcher with an opportunity to observe and record the non-verbal behaviour of the respondent.

3.6.3 Secondary Data Collection Methods

The data gathered are statistically analysed to determine if the hypotheses generated are supported. It helps to analyse the relationship between the port’s performance and the total time cargo remains in the port. Different types of data were available from both Damietta port and the Maritime Transport Sector (MTS). These data included:

1. General statistics about Egyptian ports, such as total land area, total water area, number of specialised ports, number of commercial ports, the main river ports and total length of berths.
2. National fleet, such as classification according to type of ships, age classification according to type of ships and classification according to types of owner.
3. Ships registrations, such as registration in territorial water and registration in international water.
4. The number of maritime passports issued for the holders of qualification certificates.
5. Port traffic, such as number of calls, berth occupancy, storage utilisation, handling rates and total handled volumes, in-port transportation and equipment capacity.
6. Ports' capacities, such as maximum capacity, actual capacity, and length of berths and total areas of stores.

7. Maritime Transport Sector achievements, such as development of cargo throughputs, development of ships traffic and international and local commercial development.

Data have been collected according to the four types of cargoes handled in Damietta port, namely general cargo, dry bulk, liquid bulk and containers. Data were available and have been collected on a monthly basis. For each type of cargo, port's traffic data have been edited, keyed and a categorisation scheme has been set up to cover those operations at a terminal. For this purpose, different categories of port operations have been placed by the author into five categories. Each group comprises operations that have the same purpose. This helped to understand and analyse the data collected relating to the key variables. Port visits and interviews helped to access the port traffic and capacity archives that in turn helped to identify key operations that influence Damietta port’s performance. Selected operations have been verified by the port managers and directors through interviews and observations. Data were keyed and checked to see whether there were unusual observations in certain months.

Data analysis helped to test the hypotheses developed for the research. Also, it helped the variance between the actual and estimated port performance. It indicated the reliability of the data collected. The lower the variance, the greater the reliability of the data. Data collected from Damietta port have been verified with those recorded from MTS. This helped to verify the accuracy and reliability of data collected. Data was collected using the following methods:

A. Government publications

Governmental publications and reports are important for this research. In Egypt, the government is the largest publishing body for the public sector, such as the port industry. It provides a wide variety of social, economic, demographic, financial, and other types of data and statistics. Additionally, the government provides maps for Damietta port and confidential information concerning operational information.

However, acquiring government publications was difficult as it required some knowledge of where governmental agencies locate in Egypt, which agency provides what type of information and data, how much it costs to get the required data, what type of data are available, and what type of data are allowed to be announced publicly. Five of the most useful resources regarding government organisations were:

1. Maritime Transport Sector (MTS)
2. Egyptian Maritime Data Bank (EMDB)
3. Ministry of Transport (MOT)
4. Damietta Port Authority (DPA)
5. Central Agency for Public Mobilisation and Statistics

Consulting government publications was useful because:

1. Documents enabled the investigation of the background and context of the situation and the specific problems in Damietta port.
2. Documentary analysis was a useful means of analysing the 'official' view and accessing the 'official' record of events, decisions and plans.
3. Some documents provided a measure of the impact of changes introduced during the action research process.

B. Internet

It is one of the main sources of collecting data. However, conducting searches of certain web sites was expensive in Egypt as payment was required to obtain information, data and statistics. Also, some governmental web sites provided limited information. However, more than one search engine has been used to get better results and the requisite data and information. The search engine SUMMON at the University of Huddersfield was primarily used for downloading articles, eBooks and journals. Also, the official websites for the following governmental organisations have been accessed for this purpose:

1- The Egyptian Maritime Data Bank (EMDB)

It was established to connect the main Egyptian ports (Alexandria, Port-Said, Damietta, Suez) and Lighthouses Administration (The Egyptian Authority for Maritime Safety currently), with a view to provide planners, decision-makers and researchers from various maritime fields with accurate information on all activities of the maritime Sector. EMDB publishes a variety of on-line periodicals in both Arabic and English languages, such as a statistical yearbook that covers vessels, cargoes, containers and passengers traffic in all the Egyptian commercial ports, maritime ports guide that includes information on Egyptian commercial and specialised ports, data on berths, docks, storehouses, equipment, services, tariffs, and the required documents for entering and exiting the ports, as well as the Suez Canal characteristics.

2- Maritime Transport Sector (MTS)

The sector was established to help port managers and authorities in setting the objectives and the policies of the authorities, bodies and entities, following up their application and coordinating between them, and in accessing the information technology era in the Maritime Transport Sector. Designing, implementing and maintaining the MTS web-site, covering the maritime transport activities, MTS agenda, latest news, investment guide and the result of vessels destinations committee. It also includes a database for the Egyptian and world companies operating in the field of maritime transport, as well as statistics, studies and analysis.

3- Ministry of Transport (MOT)

The Ministry of Transportation of Egypt is part of the Cabinet of Egypt that is responsible for meeting the needs of demand for transport by rail, road and sea in line with Egyptian national development plans. The website of the Ministry provides the studies and research to develop facilities and the promotion of maritime transport, including global developments in the shipping industry.

Table 3.2 – Benefits and Problems of Applied Research Methods

Technique	**Advantage**	**Faced difficulties**	**Type**
Observation	1- Provided detailed and context related information 2- Permitted to collect information on facts, not mentioned in the interviews 3- Tested the reliability of responses	1- Security issues in observing some operations, berths and warehouses related to oil, gas and the armed forces 2- Longer time was needed to observe multiple operations, which is not allowed in public ports	**Primary**
Interviewing	1- Permitted the clarification of questions 2- Provided higher response 3- Understanding the way the port managers implement their policy, strategy and supervision	1- Availability of managers, workers and supervisors for interviews 2- Operating environment 3- Credibility	**Primary**
Port visits	1- Allowed to meet the port managers and workers 2- Facilitated interviews and observations	1- Time is needed to travel to Damietta city and spending a few nights for observing operations	**Primary**

		2- Cost and expenses were high	
Literature	1- Developed general explanations for observed variations in a behaviour or phenomenon 2- Potential relationships between concepts and to identify researchable hypotheses. 3- How others have defined and measured key concepts 4- Identified data sources that other researchers have used 5- Discovered how a research project is related to the work of others 6- Permitted the examination of trends over the past	1- Data was not easily accessible 2- Information is incomplete for some key performance variables in Damietta port	**Secondary**
Governmental Publications	1- Available and verified by the Egyptian government 2- Provides in-depth details of port operations 3- Clarify the general strategy of ports	1- Payment is always required to obtain records and publications 2- Travelling is needed	**Secondary**

Internet	1- Updated information was available 2- Statistical studies could be downloaded	1- It was expensive to download statistics 2- Changes and updates were fast due to financial crises, particularly in seaborne trade	**Secondary**

3.6.4 Data Analysis

Gathering, analysing, sorting and interpreting data is required to support the use of performance measurement systems (Kennerley and Neely, 2003). Data analysis aims to explain the collected data in a meaningful way.

1. Data analytical software program

Minitab version 15.1.30 software has been used to analyse the raw data collected in Damietta port. The software helped to analyse the relationship between those performance variables and port performance. It helped to provide statistical guidance for interpreting statistical tables and graphs in a practical and easy-to-understand way.

2. Regression analysis

There are few studies applying regressions to measure port performance. In 1995, Tongzon applied linear regression to maximise berth utilisation. His study was designed to measure efficiency rather than performance for definite operations at certain terminals. This research applied ordinary least square (OLS) regressions in a wide context. Firstly, regressions were applied to examine the significance of relationships between key performance variables that influence port performance. Secondly, multiple regression models have been developed to estimate port performance. Thirdly, the research followed Tongzon's model to apply linear regression. The basic idea of OLS estimation is to choose estimates that minimise the sum of squared residuals (errors of prediction).

3.7 Research Aims, Methods and Strategy

Multiple research methods were applied to be both relevant to the aims that have been set in this research, and to enhance the contributions of this research (Robson, 2011). The research defined the problem as the lack of an effective measurement system applied in ports. This helped to focus on the research process and strategy; in turn, it helped to identify the research aims. A hypothesis has been set to explain the importance of developing such a system for the port managers. Drawing from the research perspectives in sections 3.4 and 3.5, Table 3.3 shows the research strategy tailored towards achieving the research aims, based on the methods that have been selected.

Table 3.3 – Research Aims, Methods and Strategy

Research Aims		Applied Methods	Strategy
1	To discuss the current supply chain systems and models applied to ports.	▪ Literature search ▪ Library records	Considering both performance dimensions
2	To investigate the effectiveness of the current performance measurement system in Damietta within a wider context.	▪ Original investigation ▪ Case study ▪ Governmental publications ▪ Port visits ▪ Interviews	Considering key performance variables
3	To develop DAPEMS in Damietta port.	▪ Observation ▪ Regression analysis ▪ Port visits ▪ Minitab 15.1.30	Developing DAPEMS
4	To evaluate the extent to which DAPEMS can be applied to other Egyptian ports or elsewhere.	▪ Interviews ▪ Observation ▪ Port visits	Testing DAPEMS reliability

3.8 Sample Size and Types of Data

Answering the research question and meeting the research objectives requires collecting and analysing a relevant sample size of data and using a proper sampling technique. The sample size affects the generalisation in any research. The larger the sample size, the lower the error in generalising to the population. Also, a large sample size influences the accuracy of findings, as well as the time and money invested in collecting and analysing the data. Accordingly, the sample size in this research will be 60 data points starting from January 2004 to December 2008, on monthly basis. This sample size was governed as follows:

1. A large number of samples will represent the characteristics of population at Damietta port.
2. The sample size starts from January 2004 because the port records are not available, nor accessible for these operations at different terminals before the year 2004.

3. The port reports and the Maritime Transport Sector submit monthly reports to the Ministry of Transport. Hence, the decision was made to collect monthly data.

Qualitative data has many forms for exploratory investigation. Different qualitative techniques can be used for collecting qualitative data such as films, action research observation, case studies, street ethnography, focus group and individual or group interviews. Sachdeva (2009) claimed that qualitative research methodology is designed to tell how (process) and why (meaning) things happen. Hence, it requires non-probability sampling techniques, such as experience surveys (Saunders et al., 2003).

The main purpose of the qualitative data is to provide a detailed description of events and situations between people and things. Dhawan (2010) claimed that qualitative data is concerned with qualitative phenomena which is relating to or involving a quality or kind, such as human behaviour. Thus, it is important to collect qualitative data in behavioural sciences.

In this research, the purpose is to investigate those variables that influence port performance and to examine the relationship between these predictors. This required collecting quantitative data for these predictors in order to understand their influence on performance, enhancing the generalisation of results and creating statistical models to explain events. However, observation and interviews, as qualitative data, are also used in this research for collecting data where they are appropriate to study things in natural settings (Jha, 2008). They help to understand the phenomena of port performance through explaining and studying those events and situations that affect performance. These qualitative techniques are used to deal with the quality of what is being collected of quantitative data. Qualitative data will also be considered in further research to construct qualitative measures such as port clients' satisfaction.

Quantitative data can be classified into categorical and quantifiable data. The categorical data refers to those values that cannot be measured numerically and it can be either descriptive data or ranked data. This type of data does not fit the data collected in this research. On the other hand, quantifiable data are those values that can be measured numerically and it can be either continuous data or discrete data.

Continuous data are those values that can take any value within a restricted range, while the discrete values are those values that take a finite number of values from the scale. Saunders et al. (2003) argued that discrete data increases precision than the continuous data. Table 3.4 shows the data collected for seven predictor variables at Damietta port. These predictors will be used to estimate operations time using regression analysis in Chapter Five. The criteria for the selection of these predictors are:

1- The predictors meet the port's manager's needs (see Appendix H).
2- They represent the current measures applied in the port.
3- They influence how long cargo stays in the port as discussed in the interviews with the port director and managers.
4- Predictors were applied previously in the literature for the purpose of measuring port performance.
5- These predictors represent the determinants required for developing DAPEMS (Section 5.2).

All these variables are continuous data, except the number of calls which is discrete data. The type of data collected tends to use a parametric regression as a quantitative technique. Also, time series plots performed and linear relationships were found. This justifies why linear regression analysis applied in this research.

Table 3.4 – Type of Data Collected at Damietta Port

Predictor Variable (s)	**Type of Data**
Equipment	Continuous
In-port Transportation	Continuous
No .of calls	Discrete
Total tonnes handled	Continuous
Berth occupancy	Continuous
Loading/discharging rates	Continuous
Storage	Continuous

3.9 Chapter Summary

A deductive-positivist approach was taken to develop DAPEMS. Different research methods have been applied for data collection and data analysis such as observation, interviews, port records and port visits. The research process and strategy is based on a top-down approach following a case study strategy. The research is an explanatory study as it aims to discuss the causal relationships between performance and predictor variables. In the next part, Chapter Four will examine the effectiveness of the current performance measurement system applied in Damietta port.

Chapter Four

Current Performance Measurement of Operations At Damietta Port, Egypt

4.1. Introduction

Managers in public organisations are looking for performance measurement tools that help them in planning, controlling and improving performance (Bruijn, 2002). In ports, managers are concerned with what they need to measure rather than what they can measure (Neely, 2004b). Bichou and Gray (2004) argued that a measurement approach to port performance is required. They explained that any port needs a system for identifying problems, defining obstacles and investigating the key performance variables that influence a port (Brooks et al., 2010). The literature showed that there were no recommended tools for performance measurement (Bichou, 2007). Failure in measuring port performance may mislead managers to misuse port facilities and misunderstand current problems. Selecting a proper measurement technique is based on its capability in assessing performance and how it might contribute to a port attaining its objectives.

Examining the effectiveness of current measurement systems assists in determining whether or not there is a need to develop a more effective measurement approach. That is why a case study has been considered for this purpose. By using the case of Damietta port, the research aims to provide an in-depth investigation into the development and use of performance measures in a port (Feagin et al., 1991). Hence, a case study is important to bring out details by using multiple sources of data. It aims to ensure accurate and alternative explanations, and to confirm the validity of the processes. Stake (1995) argues that the objective of using a case study is more to establish meaning to the research rather than location (Stake, 1995).

Also, the case study is a multi-perspective analysis, as it provides not only a perspective of port performance, but also of the related predictor variables and the relations between them. This Chapter aims to understand the data collection process and is divided into three sections. In the first section, the research discusses the data collection process and associated difficulties. The second section explains the Damietta port profile and the importance of Damietta city. The third section investigates the current performance measurement approach applied in Damietta port and examines its effectiveness.

4.2. 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, such as interviews and observations. Thus, a selection of relevant data collection sources depends on the terminals and facilities available in Damietta port, the time span of the study and the costs associated with data gathering (Sekaran and Bougie, 2010).

Yin (2003) suggested six sources for data collection using a case study strategy. These are documentation, archival records, interviews, direct observation, participant observation, and physical artifacts. However, he argued that not all these sources should be used in every case study. In this research, data collection sources involve documentation, port records, interviews, observation and port visits.

1. Documentation – Recently, the Egyptian government appointed international consultant agencies, such as Japan International Cooperation Agency (JICA), to produce port performance reports. These studies were useful for providing detailed information about key performance variables in the ports, port hinterlands, port facilities and port operations.

2. Port records – These records are useful as they provide archival records. They include maps, charts, port traffic, yard capacity and port capacity and productivity. These records have provided all the data required concerning predictor variables that were used to develop the DAPEMS system.

3. Interviews – Interviews were conducted with three port directors, seven port managers and 40 workers to procure informed opinions on key variables. These were used to confirm previously gathered data.

4. Observation and port visits- this involved 13 visits to Damietta port between August 2007 and June 2011. They aimed to ensure the reliability of the gathered data.

4.3 Difficulties in the Data Collection Process

In Damietta port, there were difficulties in collecting data. The port is public and it is operated by the government. The Ministry of Transport and the Ministry of the Interior have set very strict rules for obtaining data and detailed information. The researcher faced the following difficulties in collecting data in Damietta port:

1. Observing the full port operating environment was limited to pre-identified terminals, operations and cargoes.
2. Meetings and interviews with the port managers and directors were undertaken according to very strict rules and routines.
3. Damietta port is located in Northern Egypt on the Mediterranean Sea, about 5 hours driving time from Cairo where the researcher is based. It was a costly use of both time and monetary resources to hold meetings, interviews and undertake observational research in the port.
4. Each port visit required official permission. The researcher's national identification card had to be submitted to the State Security Unit at least one week prior to the visit to obtain permission to visit the port and delays were common, resulting in missed interviews and meetings.
5. Most port records and documents received were hand-written. It required time and effort to transcribe data into an electronic format necessary for input into Excel and Minitab software.

Fortunately, DPA provided all the necessary data, information and access necessary for completing this research (see Appendix C).

4.4 The Importance of Damietta City

Historically, Damietta city was known as Tim Any or Tamit in ancient Egypt, Tamyatish in the Roman period and Tamiati in the Coptic period. Currently, the city is known as Damietta. It was considered an important port during the Mamluk period, as it was the main exporter of rice to the Ottoman Empire.

Figure 4.1– Damietta Location

Source: World Atlas, 2010.

Figure 4.1 shows that the city lies between Lake Manzala and the river Nile, on the Mediterranean Sea, and it is around 210 km from Cairo city. The Damietta governorate covers an area of 910.3 km2, representing 0.1% of the Egypt Republic's area, and encompasses 10 cities, 47 rural units and 85 villages. The population is about 1.1 million people, and about 39% of them have high skills, experience and are well trained for maritime and fishing activities (Ministry of Transport, 2009).

Damietta city is famous for growing wheat, maize, cotton, rice, potatoes, lemons, grapes, and tomatoes. The economic activities depend on skilled human resources and on small production units run by the private sector. Damietta has a high reputation for its handicraft industries including furniture carpentry, dairy products, fish processing, oil and soaps, pressed woods, rice mills and grain grinder. In addition, Damietta has the largest fishing fleet in Egypt, more than 60% of total fishing vessels. Damietta also has a large shipyard for building ships.

4.5 Damietta Port Profile

Egypt has 15 major commercial ports under the control of the Maritime Transport Sector and their respective Port Authority, affiliated to MOT (Ministry of Transport, 2009). Among them, there are three international hub ports, West Port Said, East Port Said and Damietta Port. Damietta port has a strategic and economic role as it mainly handles freight from Asia and the Middle East to Eastern Mediterranean Sea countries and Europe.

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 (DPA, 2007). Damietta Port is located in Northern Egypt on the Mediterranean Sea at Lat 31° 26°N, Long 031° 48°, and it is about 8.5 km west of the Damietta branch of River Nile. It has a strategic location near the Suez Canal and other Mediterranean hub ports, particularly East Port Said port. It is located 70 km to the west of Port Said Port and 200 km east of Alexandria Port. Its unique location on the Mediterranean Sea makes it an excellent crossroads between the Far East and Europe, where major shipping lines are operating .

It has five terminals and the port installations extend across an area of 11.8 sq. km as mentioned in Appendix B. It is considered as a multi-purpose port and it is linked with different modes of transport such as road, rail, air, pipeline and inland waterway.

Figure 4.2 shows that the port occupies an area of about 13 sq. km and it is subdivided into two main parts; the shipping area and water area. The shipping area includes an inland section that consists of 18 berths and quays. The water area is composed of an access channel connecting the shipping area with the Mediterranean Sea and the main basin.

Figure 4.3 shows that the Port was established in a coastal embayment some distance inland in order to be protected from winter storms. The port can be broadly subdivided into five divisions as follows (Appendix B):

1. The Petrochemicals and Liquefied Natural Gas (LNG) complexes to the west (under-construction).
2. The industrial free zone to the east.
3. The water area (port basin) and the surrounding platforms and berths.
4. The southern parts contain most amenities and services of the port such as, administration buildings, fire station, water pumping station, agricultural quarantine and accommodation houses for the workforces.
5. Berths and quays of the port occupy the central area and include the container and general cargo berths to the west and the bunkering and grain berths to the east.

It is important to state Damietta port’s strategy that has been provided in the port records and documentation as follows:

'Contribution in raising economic growth through achieving maximum productive capacity of the port and improving the performance rates according to effective quality management system and port users satisfaction'.

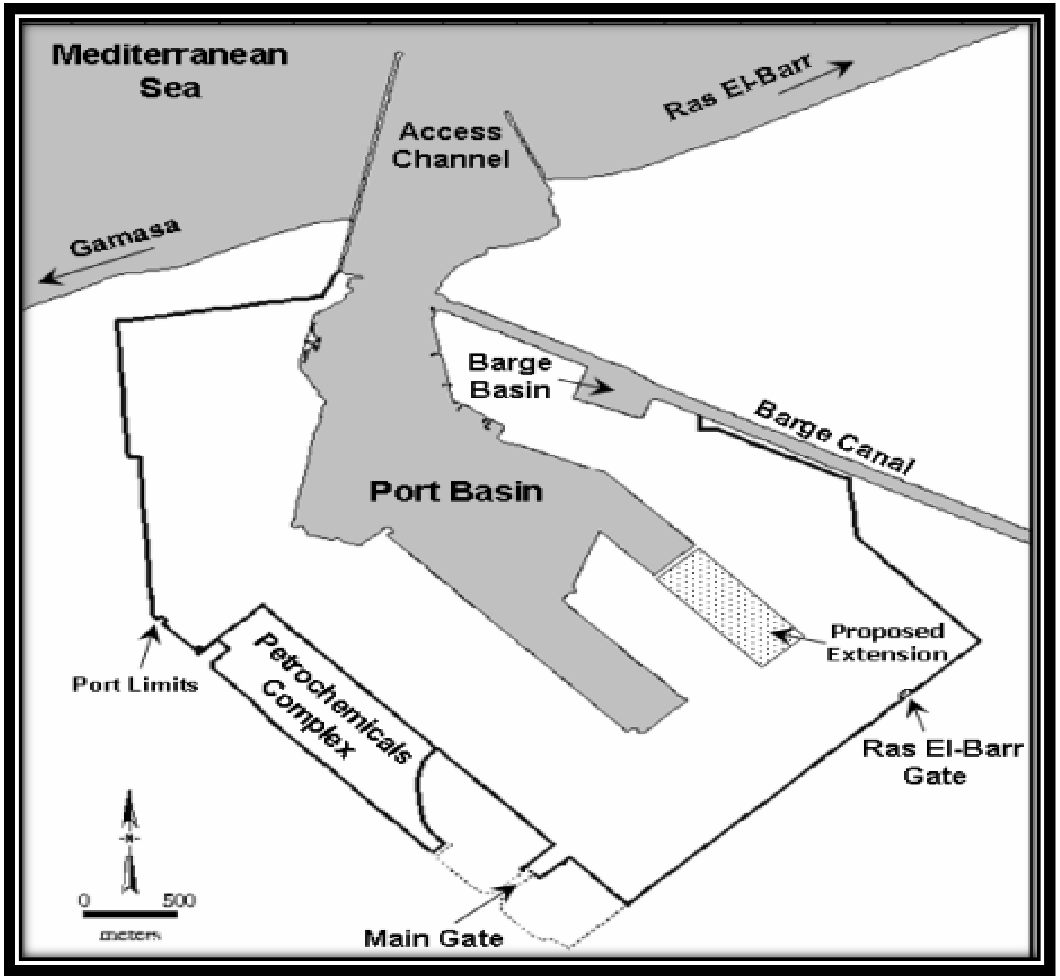


Figure 4.2 – Damietta Port Layout

Source: DPA, 2011

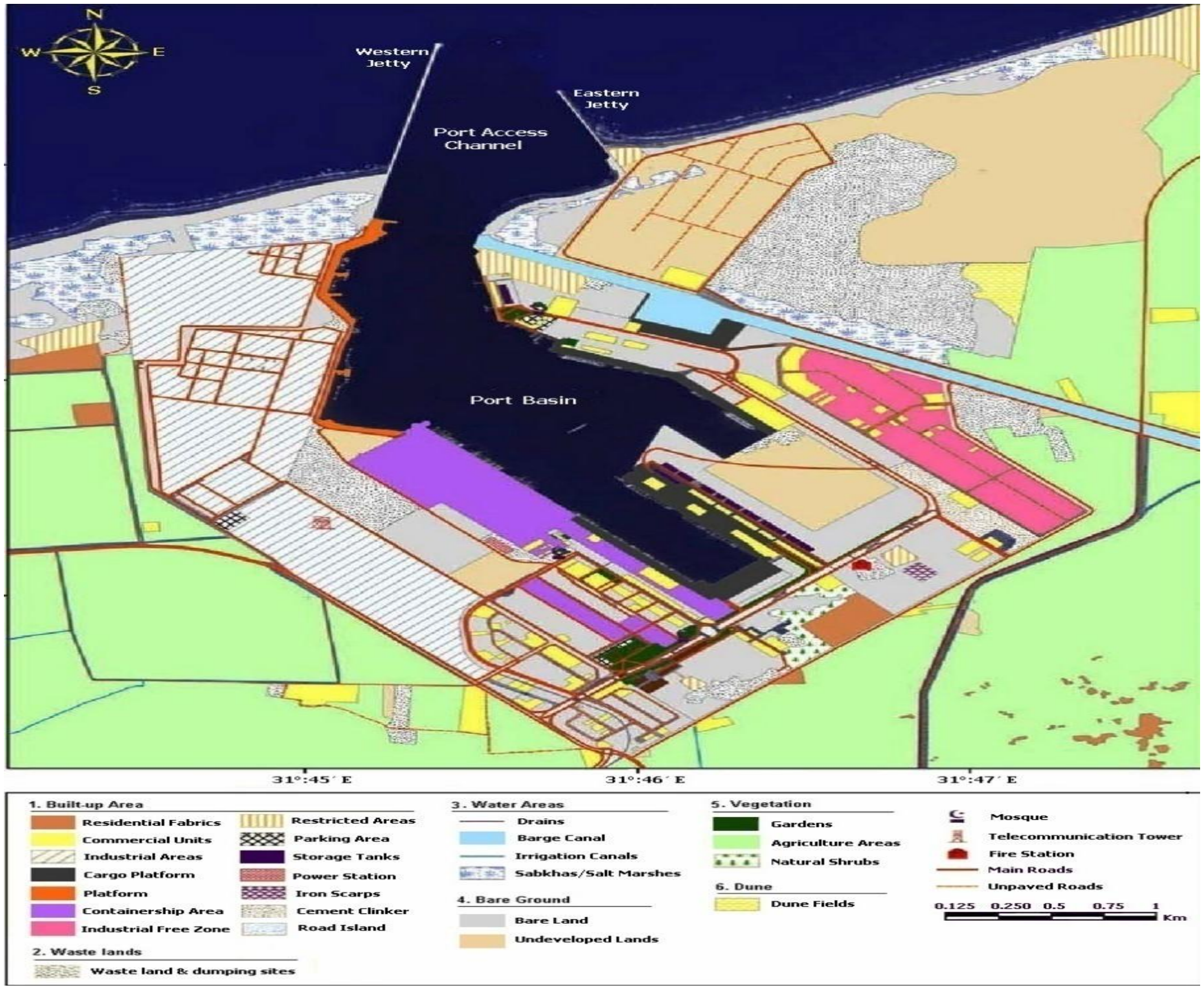


Figure 4.3- Land Use of Damietta Port

Source: DPA, 2011.

4.6 Factors Affecting Damietta Port Performance

Performance of public ports is traditionally based on data recorded by the port authorities, such as traffic recordings, port tariffs and standing times (Fourgeaud, 2000). In Damietta port, managers and workers are working in a complicated and dynamic operating environment for many reasons. Firstly, the port is located in Damietta city, where 60 % of gross production of furniture exits in Egypt. This explains the increasing demand for timber imports as raw materials through the port. Secondly, furniture exports increased during the last five years. Thirdly, importing grains, iron and agricultural products have recently increased through Damietta port, due to the availability of storage yards and warehousing areas in the port (DPA, 2011).

Fourthly, exports of cement and clinker are increasing, as many leading cement companies direct their shipments of exports through Damietta port. Lastly, there are high flows from and to the ports either for imports and exports purposes due to the available transportation network that links the port with the rest of the country. Figure 4.4 shows the main market areas for imports and exports at Damietta port.

Figure 4.4 – Flows from and to Damietta Port

Source: DPA, 2011

Damietta port has many hinterlands that are located in Cairo city, Alexandria city, Port Said city, Damietta city and Delta cities. These consumption areas affect the port economically because 75 % of their imports are transported through Damietta port. Imports of grains, timbers and agricultural products are shipped to the port and then delivered to its hinterlands. Interviews showed that many vendors and factories located in Upper Egypt prefer to export their products through Damietta port for many reasons:

1. The port is connected by many modes of transport which facilitate the movement of cargoes from and to the port.
2. The port terminals have been designed to handle high capacities that are not available in other ports in Egypt, particularly for cement. These terminals facilitate the movement of products in loading and discharging operations.
3. Many leading commercial companies in Egypt have long-term contracts with regular shipping lines calling at Damietta port.
4. The port is close to the Suez Canal and the transhipment trade has sharply increased.
5. Port productivity can be maximised to meet any increase in demand in the future due to the availability of land. This gives the port the potential to increase the number of storage areas in the future.
6. Many natural gas and petroleum companies such as SEGAS, UGDC and the Egyptian Petrochemical Company are establishing refinery stations inside the port for storing, transporting, exporting, marketing and shipping natural gas, petrochemical products and petroleum extracts through Damietta port. These companies are establishing a special berth inside the port for exporting petroleum extracts.

It is obvious that port operations are very complicated and port performance is affected by many internal, external, technical, economic and operational factors. In order to develop a port performance measurement system, there is a need to understand how the port managers currently measure their performance. Therefore, the following section will investigate the current performance measurement approach applied in Damietta port and examine the effectiveness of this approach.

4.7 Current Measurement Approach in Damietta Port

The aim of this section is to analyse 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, observations, the internet and the literature review.

4.7.1 A Number of Calling Ships

The Damietta Port Authority (DPA) takes into consideration that the number of ships calling into 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 to understand the streamline flow of all types of cargoes. It shows the inbound and outbound volumes of cargoes. Also, DPA believes that determining the number of calling ships will contribute to forecasting future volumes. The number of calling ships comprises two key performance indicators: number of calling ships and number of shipping lines.

- Number of Calling Ships

DPA records the number of calling ships per month as a key performance indicator. Then, it compares total number of ships and total volumes handled in the port on a monthly and yearly basis to show if there is an increase or decrease in total number of ships calling. An increase or a decrease in the number of ship calls is being used as an important indicator to identify performance.

Tongzon (2009) argued that the higher frequency of ship visits translate into more choices for freight forwarding and shipping agencies in selecting a port. He emphasised that increasing the number of calls gives more flexibility and lower transit time and transport costs. However, he did not evaluate the congestion and overbooking that may arise due to an increase in the number of calls, as well as the extra cost generated by this congestion.

The number of ships calling at Damietta port has increased significantly since its opening in 1987. The port received 3259 ships in 2010 as shown in Figure 4.5. Interviews and the port records indicate that DPA considers an increase or a decrease in a number of ships as an indicator for assessing the port's performance. From the interview with the port's directors, it was concluded that DPA builds their decisions on this measure. For example, DPA decided to expand the port facilities in 2005 following a 25 % increase between 2002 and 2004. It is important to highlight that the number of calls incorporates the total number of all types of ships calling at the different terminals.

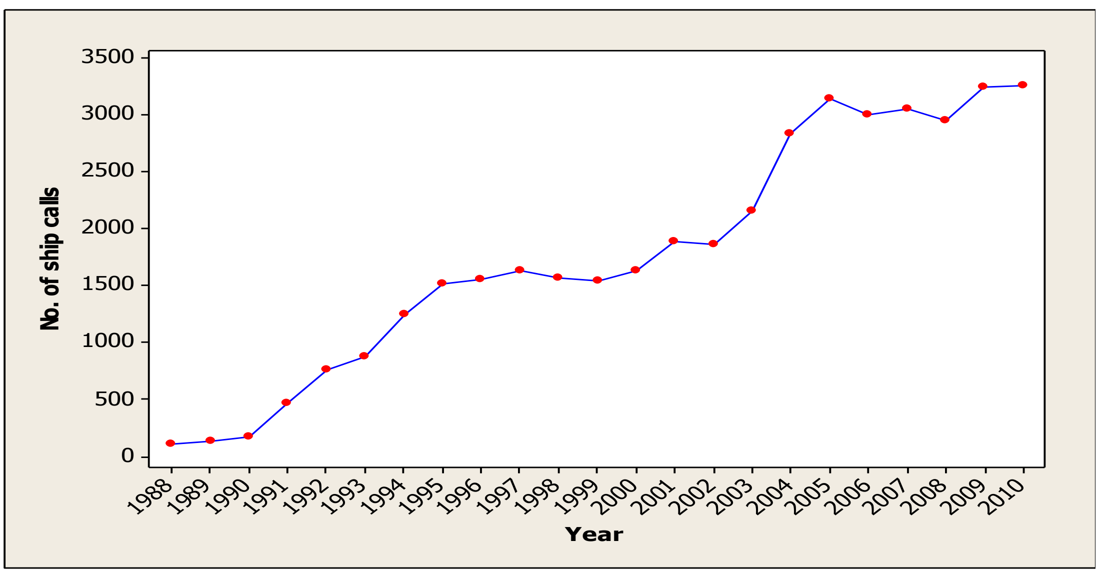


Figure 4.5 - Total Numbers of Ships Calling Damietta Port from 1988 to 2010

Source : MTS, 2011

DPA categorises the ships calling at the port into two categories: container ships and general cargo ships. In this way, DPA sets a strategic plan for future forecasting and expansion at certain terminals. However, the port's records, governmental publications and interviews with terminal managers revealed that the port records the number of ships for other types of cargoes such as liquid bulk and dry bulk. Little attention has been given towards these types of cargo by the port managers in the process of evaluating the performance. Dry bulk ships constituted about 11 % and liquid bulk ships represented about 8 % of total ships called at Damietta port in 2010. From the port managers' perspective, interviews showed that improvement in port performance occurs normally when the number of container and general cargo ships increases. They believe that any increase or decrease in the number of ships of both types will, in turn, affect total volumes handled at the port.

As discussed in the literature, most current performance measures focus on containerisation rather than generalised cargoes. Interviews denoted that containerisation measurement is easier, where containers can be easily classified into standard sizes or dimensions. Standardisation facilitates quantifying the number of handled containers, and the number of stacks and trucks can determine how many containers can be carried (Talley, 2006).

However, MTS (2011) announced that general cargo ships account for between 27.8% and 37.3% of total ships called at Egyptian ports. Also, liquid bulk ships account about 6% and dry bulk ships account about 6.1% of total ships. Therefore, relying solely on the number of container ships is not appropriate for measuring the port's performance.

The researcher argues 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. This is because many container ships, *for example*, may call at the port carrying only a small number of containers whilst some general cargo ships may only carry light cargo. This means that there are other indispensable variables that should be taken into consideration in measuring the port performance in addition to the number of ships.

- Shipping Lines

The liner trade plays a major role in providing efficient and cost-effective movement of cargoes in modern logistics systems, particularly in ports. Liner shipping is a major link in global supply chains and in ports, as it involves the transportation of high value and more time sensitive cargoes. Shipping lines are more important than the tramp industry as the port will receive benefits from liner ship calls in terms of regular stevedoring operations, larger quantities and optimum utilisation of the port facilities.

Shipping lines are used by DPA as a key indicator for measuring port performance. This is because shipping lines are considered as one of the main port clients. Each shipping line possesses a number of ships, which call regularly and frequently at the port on a scheduled basis. Thus, when a shipping line moves its ships from one port to another, this negatively affects port performance by reducing the number of ship calls. In Damietta Port, the number of container ships decreased between 2004 and 2005 by 20 ships, with a further decline of 195 ships in 2006. The port operations manager explained that the reason behind this decrease was due to:

1. The Maersk shipping line moved its ships to East Port Said Port.
2. The Maersk shipping line recently took over P&O and NED Lloyd, and then redirected all their ships from Damietta port into East Port Said Port.
3. C.M.A shipping line has moved 30% of its container ships to Beirut Port, Lebanon, due to inadequate depth in Damietta for its new ships.

However, the researcher argues that the movement of some shipping lines from Damietta to other ports has not necessarily had a negative effect as other new shipping lines have begun to call at the port. It is observed that some shipping lines moved from Damietta port, while other new shipping lines called at the port. Between 2003 and 2006, the port records displayed that some shipping lines moved their ships to other ports as discussed above, and four new Chinese shipping lines have started to call at the port.

On the other hand, observation and port visits showed that Damietta port suffers from a lack of feeder ships. Shipping lines are competing in the Mediterranean basin through sailing mother ships to serve Middle East markets. Mother ships are normally being served by feeder ships. A small feeder ship is a small container ship normally operated by independent operators to serve between a hub port and other smaller ports nearby. A lack of feeder ships causes some shipping lines to direct their mother ships to other ports. This may explain why those shipping lines left Damietta port. Ghoneim and Helmy (2008) argued that the number of shipping lines visiting Egyptian ports is affected by infrastructure which is in poor condition due to lack of quays, equipment, facilities and maintenance.

It is concluded that DPA measure their port performance according to how many ships call at the port and how many shipping lines currently call at the port. A more effective measurement system is needed to assist in the identification of problems.

4.7.2 Time Measures

The value of time is very important in ports. Any delay in loading and discharging cargoes would lead ships to spend more time at berth, and other ships will have a longer waiting time in anchorage areas. In addition, ship owners will be dissatisfied due to an increase in the ship turn-around time. In Damietta port, berth occupancy is used as a performance measure. However, higher berth occupancy may result from operational delays resulting in a ship spending longer at berth. Hence, high berth occupancy might be due to longer occupancy by fewer ships. Thus, berth occupancy is not an appropriate performance measure.

Port records and interviews showed that DPA has records for standing times, berthing times, un-berthing times, berth occupancy time and clearance time. But the interviews showed that the port managers use only berth occupancy in measuring performance, with no regard to other measures. Figure 4.6 displays the ship turn-around time developed by this research. It helps to identify and understand the determinants required for designing DAPEMS in Chapter Five. The line from point 1 to point 7 presents ship turn-around time as the total time that a ship stays in port. An increase occurring at any stage on the line between 1 and 7 will raise the ship turn-around time, and vice versa.

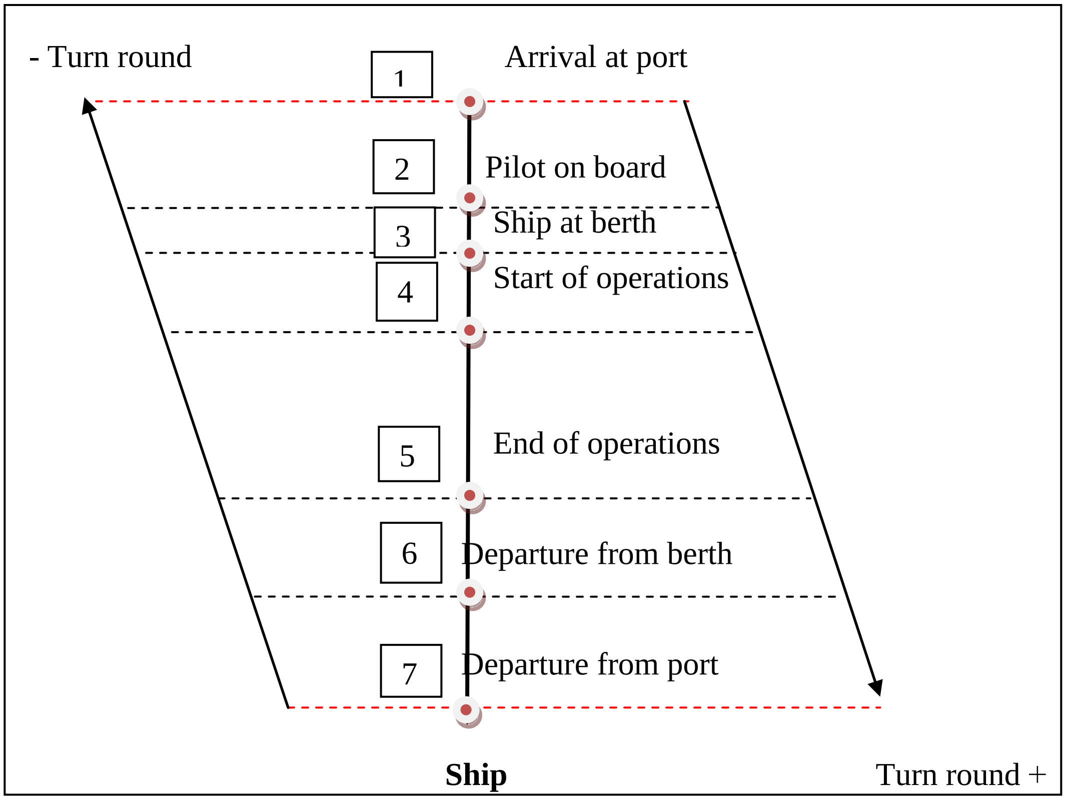


Figure 4.6 - Ship-Turn-around Time

Increasing a ship turn-around time might be due to a delay in operations. Figure 4.6 divides the operations into seven parts. The delay could be due to unavailability of berths, unavailability of required storage areas, inadequate of cargo handling equipment, or limited port productivity to meet the increasing number of ships. The seven parts are determined in Table 4.1.

Table 4.1 – The seven Parts of Ship Turn-around Time

Time Operation	Time (dd-hh-mm)	Description
Ship turn-around time	Time between 7 and 1	Refers to the total elapsed time that a ship stays in port from arrival until departure
Service time	Time between 6 and 2	Refers to the total elapsed time of provided pilot until departure date
Time at berth	Time between 6 and 3	Refers to the total elapsed time of a ship at berth until leaving berth
Operating time at berth	Time between 5 and 4	Refers to the total elapsed time of starting the operations until terminate the operations
Preparing for operations	Time between 4 and 3	Refers to the total elapsed time of a ship at berth until starting operations
Time elapsed to arrange documents	Time between 6 and 5	Refers to the total elapsed time from the termination of the terminal operations until departure date

DPA collects time-related data to inform stevedoring companies, particularly Damietta container and cargo handling company (DCHC). This helps shipping agencies and middlemen to prepare adequate and proper handling equipment. These data are waiting time in port and in anchorage areas, and are used to evaluate berth performance only.

- Ships Waiting Time

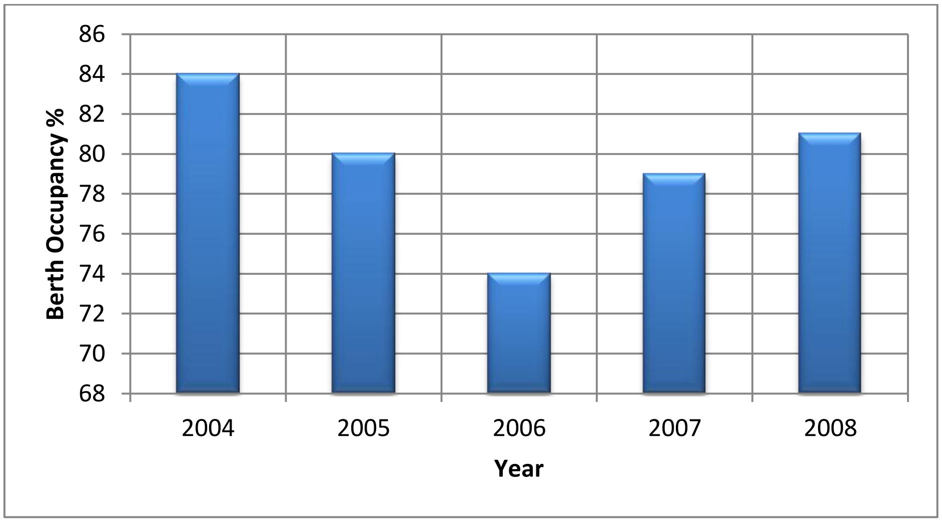


Figure 4.7- Container Berth Occupancy Analysis

Source: DPA, Annual Report, 2009

Figure 4.7 shows that the container berth occupancy (B.O.) declined from 84% in 2004 to 72% in 2006 before recovering to 81% in 2008. These variations may result from changes in the number of calling ships, improvements in cargo handling or because of other factors. The fluctuations in berth occupancy show that B.O. is an inappropriate performance measure in ports.

It is observed during the port visits that work at the container terminal proceeds very slowly. DPA claims that this slowness is because the operations managers apply two different systems for loading and discharging containers in a single terminal: Rubber Tire Gantry (RTG) system and reach stackers system. This results in handling containers slowly. However, the researcher argued that the RTG system can be used in high-density operations for handling full containers, while the reach stackers system can be used in low-density operations for handling empty containers. Hence, using two handling systems in a single terminal do not necessary lead to slow operations.

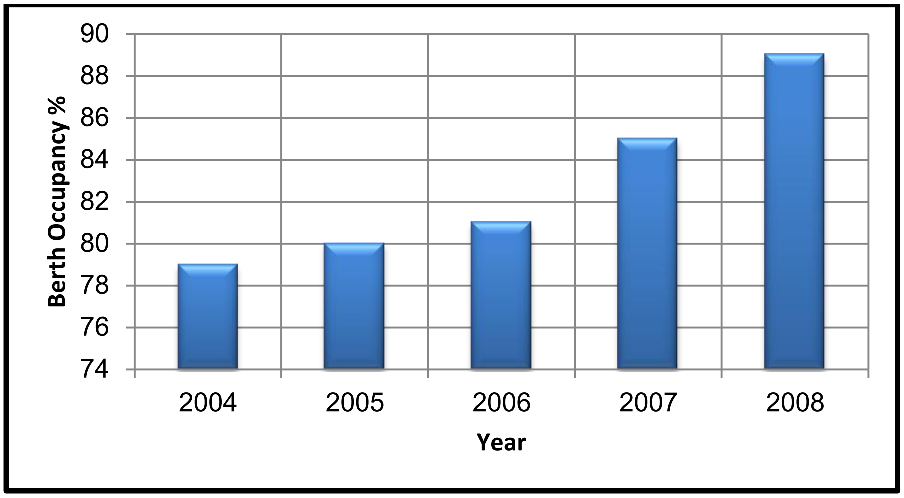


Figure 4.8- General Cargo Berth Occupancy Analysis

Source :DPA, Annual Report, 2011.

Figure 4.8 shows that the general cargo berths occupancy increased between 2006 and 2008. The DPA believes that increasing the berth occupancy was due to increasing the number of calling ships into 1638 ships in 2006; comparing this to 1148 ships that called at the port in 2008. The port records showed also that waiting time decreased in 2006. This explains why the port managers used grains berths for loading and discharging general cargoes to minimise waiting time. In the year 2006, there were 1488 ships waiting in the anchorage area. The average waiting time was 24 hours per ship.

Observations found out that increasing general cargo berth occupancy was not solely due to increasing the number of calling ships, but was due to misusing cargos handling equipment on berths, improper planning of the transportation network inside and outside the port and the improper planning applied in the storage areas to meet the increase in demand. Fouad and Lawler (2008) argued that operators at Damietta port are usually bagging grains using bagging units at the general cargo berths, and then they load bags into trucks. They claimed that this handling method triples the time to discharge a ship.

- Total waiting time in port

Table 4.2- Ships Waiting Times in Anchorage Area

Year	No of ships calling at the port	No of ships which hook to wait in anchorage area	Waiting ships %	Average number of hours for waiting time in anchorage areas
2004	2724	1475	54%	26 hours/ship
2005	2977	1586	53%	28 hours /ship
2006	3022	1488	49%	34 hours /ship
2007	3055	1475	48%	34 hours /ship
2008	2950	1510	51%	29 hours /ship
2009	3245	1570	48%	34 hours /ship
2010	3259	1572	49%	36 hours /ship

Source: DPA, 2011.

Table 4.2 shows that the waiting time in the anchorage areas has increased from 26 hours per ship in 2004 to 34 hours per ship in 2006. An increase in waiting time in the anchorage area resulted in an increase in the waiting time in port. Table 4.2 shows that fewer ships were forced to wait in the anchorage area in 2004 and 2007. This was due to increased handling rates, availability of storage areas or an increased number of berths (or their lengths). However, the average number of hours for waiting per ship increased to 36 hours per ship in 2010, compared to previous years.

This means that there are other predictor variables which influence waiting times in port and at berths. These factors should also be determined and incorporated into the design of a measurement system. Also, it has been observed that DPA ignores other important factors such as standing time. It is not efficient to use waiting time in port or at berth in correlation only berth with occupancy. Other factors should be considered, such as berthing time, un-berthing time, standing time and clearance time. Also, waiting time and standing times should be considered in a different way to measure performance.

4.7.3 Total Tonnes Handled at the Port

DPA focuses their measurement on sea access. It applies the economic and financial indicators which are usually related to the maritime side. The port director argues that those indicators can help in determining the actual port performance. These indicators are gross tonnage (GRT) and twenty foot equivalent unit (TEU) and forty foot equivalent units (FEU).

However, the focus is on containers where calculations are easier than for other types of cargoes. Thus, managers record total imports and exports to provide a total number of TEUs handled at the port on a monthly basis. TEUs have always been used as a measurement of productivity for container terminal output.

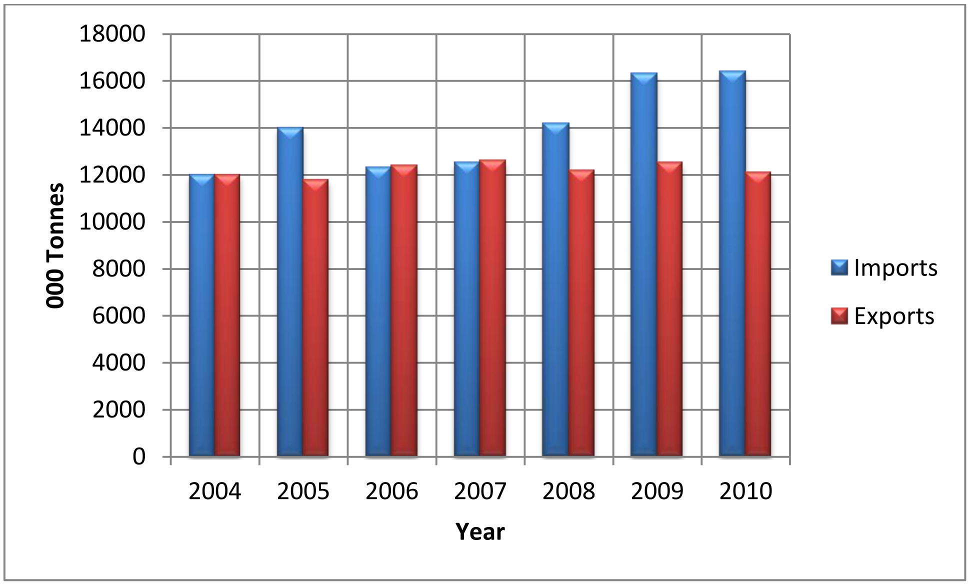


Figure 4.9 - Total Containers Handled in Damietta Port

Source: DPA, 2011.

Figure 4.9 shows that there was a decline in total container imports between 2006 and 2008, while there was a decline in container exports in the year 2005. Usually, MTS applies this indicator (total tonnes handled) to measure the overall performance of all Egyptian ports and the Egyptian maritime sector. Containers are usually handled in special terminals in ports, which are known as container terminals. The container terminal is the interface between sea and land and thus it is a critical link in the supply chain by means of which containers are delivered to final port clients. A container terminal is a special facility that provides a package of services and activities to handle and control the flows of containers from ships to the port and vice versa. As a result of its importance, the performance of container terminals is often used as a proxy for overall port performance.

The efficiency of the container terminal system occurs in case of coordination, cooperation and integration between all these participants. In Damietta port, managers claimed that the performance of the container terminal decreased between 2004 and 2006. It seems apparent that the reason for this decrease was caused by moving some shipping lines to other ports such as East Port Said Port.

However, observation and port visits revealed that the reason for this decrease was due to non-integration between all participants in the containerisation system in Damietta. But the question is *why is there no integration between all participants*? The researcher argued that every participant in Damietta container terminal has a different goal. From the standpoint of terminal performance, the terminal operators have a goal to focus on minimising handling cost per container and maximising profit; for the port authority, the main goal is to increase the annual throughputs and to ensure that all facilities are fully utilised; for the stevedores, the main goal is to increase total containers handled; and for shipping lines, the main goal is to minimise the waiting time for container ships in the port. Therefore, they have different goals where each party tries to accomplish his own goals, regardless of other participants' goals (Ghoneim and Helmy, 2008).

In order to measure the performance of the terminal, it is important to quantify all activities that are provided within the terminal. These activities comprise storage area, transportation infrastructure, handling equipment availability, layout, container freight station, custom regulations, safety rules, environmental laws, and intermodal scheduling. Actually, DPA does not consider all of these activities. It focuses only on how many containers are handled at the terminal with no regard to other activities. This makes this indicator inefficient in measuring the terminal and port performances. Hence, the current performance measures that are being applied in Damietta port are not sufficient as they do not consider relevant variables and focusing on containers.

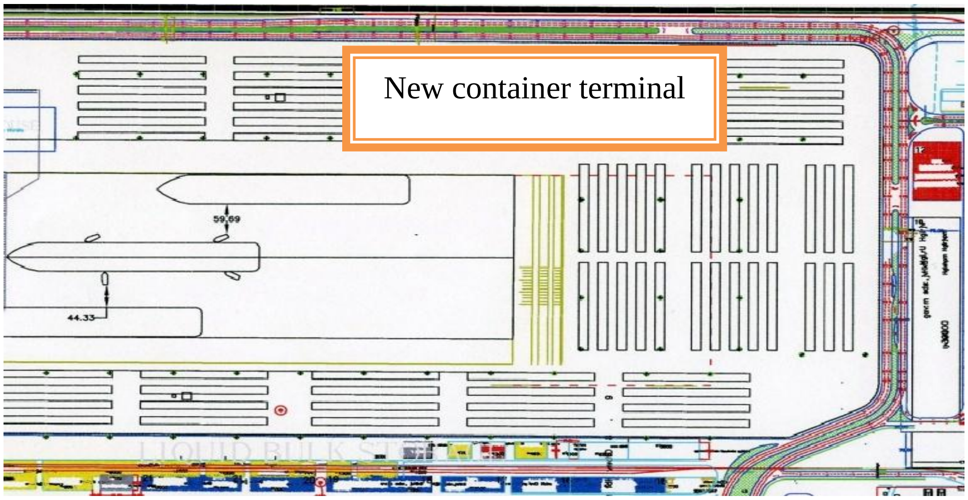


Figure 4.10- New Container Terminal in Damietta Port

Source: DPA, 2008

Figure 4.10 shows a typical container terminal standard that DPA plans to establish in future alongside the current container terminal. It consists of the water-side berth for docking the ships, a large paved yard for storage of containers, specialised cranes, tractors and other equipment for handling the containers from the ship to the storage yards, a computerised gatehouse to control entry and exit of containers from the yard on trucks, and various maintenance and administration buildings. The port authority is proposing that the new terminal will handle 4 million TEUs.

As mentioned earlier, the port managers take into consideration the total tonnes handled of containers and general cargo in measuring the port performance, with no regards to other types of cargo. However, port records show that a decrease or an increase in the number of ships and volumes of other types of cargo can affect the port's performance. For example, grain ships decreased in the year 2006 by 26 ships and consequently the quantity handled in the port reduced by 706,160 tonnes.

Table 4.3 - Analysing the Number of Grain Ships Calling at Damietta Port

Year	2004	2005	2006	2007	2008
Wheat	48	77	46	80	65
Maize	74	77	60	76	43
Other grains	37	21	43	49	28
Total	159	175	149	205	136

Source :DPA, 2010.

Table 4.3 shows that there was a decrease in the number of grain ships. The decrease in total grains was due to a decrease in the number of Maize ships by 31 ships in 2008 comparing to 2004. Interviews displayed that there were two sectors owning and distributing grains; public and private sectors. It was observed that these sectors were the cause of the decreasing number of grain ships in Damietta.

The public sector owns a higher quantity of grains than the private sector. Hence, when the public sector reduced the quantity that was planned to be distributed according to the proper schedule that has been set by the purveyance association, this caused a delay in the discharge rate, by 5970 tonnes per day. Consequently, it caused a commutation at the grain terminal inside the port. This commutation of wheat results in reducing the efficiency of cargo handling equipment in the grain terminal, making congestion in storage areas and yards in the port, and affecting the flow of grains from ships to the storage areas. Therefore, two indicators can be concluded here. The first indicator is the distribution programmes of wheat from grain terminal in Damietta that do not fit the capability of equipment in term of discharge rate as shown in the Table 4.4.

Table 4.4- Distribution Rate and Discharging Rate for Wheat in Damietta Port

General rate of discharge in the port	Distribution rate for wheat by public sector	Gap (tonnes)	Percentage
10270 tonnes /day	4300 tonnes /day	5970	139%

Source : DPA, 2007.

The second indicator is the transport network that links the grain terminal with the rest of the country. DPA records showed that the average number of trains that have been used to carry wheat is two trains per day, while the average number of vehicles in road transport that have been used to carry wheat is 58 vehicles per day.

By examining the effects of the decrease in grain ships on the port's performance, and comparing these rates with the optimum capacity of the grain terminal in the port, it was found that the terminal can handle 7000 tonnes per day which fit to load five trains per day or 241 vehicles of road transport per day. On the other hand, it was found that the port managers rely on experimental and qualitative methods rather than quantitative methods in measuring the performance of such cargoes and the optimum capacity that can be carried by means of transport. In other words, there is an improper plan in place for total cargoes at the terminal, handling rates of equipment and capacities carried by different modes of transport.

For timber ships, the port handled in excess of 31,842 more tonnes in the year 2006 than in 2005. Also, the discharging rate of timber has increased in 2006 than the year 2005. It has been observed that the waiting time for timber ships was 2.5 days per ship in the year 2006 compared to 2.4 days per ship in 2005.

In addition, there was a decrease in total quantities of agricultural products that were handled in the year 2006 by 53,050 tonnes than in the year 2005. This was due to the increase of timber imports that serve the furniture industry in Damietta city. It illustrates also that both the number of iron ships and total quantity of iron handled in Damietta have been increased in 2006 by 342,195 tonnes, and about 33, 3 % than 2005. This increase was due to the availability of huge storage yards, particularly close to the discharging berths for iron.

It can be concluded that DPA measures their performance in terms of the total number of ship calls and total volume handled per month, regardless of other factors and variables which have great effects on port performance such as inefficient handling rates that can lead to an increase in berth occupancy rates and harbour congestion (Fouad and Lawler, 2008).

As a performance measure, berth occupancy is being applied to avoid over-booking. Zouari and Khayech (2011) claimed that calculating berth occupancy does not help to identify weaknesses at berths. It is obvious that the port has no formal performance measurement system. Current performance measures and indicators are insufficient and unreliable, and designed for containers and general cargo, nor for other types of cargoes. Talley (2007) argued that a port should not only be concerned with the physical handling of cargo, but also whether it can compete for attracting more volumes and clients.

4.7.4 Equipment and Storage Measures

Loading and unloading ships can improve the efficiency of quay cranes and improve the performance of the container terminal and all other terminals, which in turn affects the port's performance. The gross number of crane hours is the total time during which the cranes have been used, irrespective of the delays, whether due to breakdowns, operational delays or external factors such as rain.

Quay cranes are the most expensive single unit of handling equipment in port container terminals, and because of this, one of the key operational bottlenecks at ports is quay crane availability. By improving quay crane utilisation, ports can reduce ship turn-around time, improve port productivity and improve throughput of freight transportation (Kim and Kim, 1997; Goodchild and Daganzo, 2007). For improving crane efficiency, ports have undertaken various projects such as renovating and adding terminals, constructing and expanding intermodal facilities and implementing new IT infrastructure.

Because crane productivity is so important, ports have also invested in various crane utilisation improvement strategies. There has been little academic research that addressed the problem of double cycling, or measuring crane performance in ports. Port research typically focused on strategic design planning issues, such as the number of berths, the size of storage space and the number of various types of equipment to install.

Other operational planning and control problems have been addressed including berth scheduling (Park and Kim, 2003), quay-crane scheduling, stowage planning and sequencing, storage space planning , and dispatching of yard cranes and prime movers. To date, most of this work utilises queuing theory and stochastic models, simulation, and classical operations research techniques such as routing, network, and scheduling problems (Kim and Kim, 2002).

The degree of efficiency of cargo handling equipment can also affect cargo throughput at a berth, cargo handling cost, and the distribution cost (Branch, 1997). Port managers and authorities select the most suitable types of cargo handling equipment that can attract tonnage. Branch (1997) identified these factors that influence the determination of suitable types of equipment as follow:

1. The nature of cargo
2. Weather and tidal conditions
3. Type of vessel
4. Handling cost and general safety
5. Competitive situation with other ports
6. International trade
7. Resources available at ports
8. Maintenance costs

In Damietta Port, a private company is responsible to operate these cranes and equipment that are currently used in handling, loading and discharging cargoes. DCHC started operation in 1999. It deals with international shipping lines for loading and discharging cargoes, such as CMA, CSCL, APL, NYK, MOL, PIL, YML, MISC, HMM, HSD and Cosco. In 2008, it has started ongoing investment in facilities and equipment. Interviews with the DCHC managers showed that the company applies a state of the art management system to ensure efficient vessel and gate movement, and wants to increase the water depth alongside the container berths.

However, DCHC ignores other important factors such as storage areas. Whilst the total number of ships and total volumes have increased over the years, the port capacity is fixed at 19 million tonnes a year. More storage areas, yards and warehouses are required. Also, less attention has been given to the equipment capabilities at other terminals. DCHC focuses on investing on dredging more depth at certain terminal, regardless of replacing existing cranes and handling equipment. It is inefficient to ignore storage capacities in any measurement approach.

4.8 The Effectiveness of Current Damietta Measurement Approach

Interviews with general managers proved that the port does not consider storage measures in measuring the port performance. DPA argues that the port has huge storage areas and warehouses, and any increase in demand in future will not cause a real problem.

It is obvious that Damietta port managers focus on productivity measures more than performance measures in assessing their port performance. Other managers misunderstand the difference between these two concepts. It is very important to distinguish between port productivity and port performance. Productivity is a measurement of the effective use of port resources. It refers to amount handled per terminal, while performance refers to how to improve the understanding of the factors of productivity and how they are related to each other.

Observationally, every manager and participant in Damietta port has a primary responsibility in achieving a productive use of resources in different activities. But no integrated performance measurement system has been applied to measure the port performance. Partial measures are currently used in Damietta port. As in other African developing countries, managers usually apply partial measures and focus on productivity rather than performance. Table 4.5 shows the current performance measurement framework received by DPA in 2011.

Table 4.5 Current Performance Measurement Framework at Damietta Port

Volumes (000 tonnes)

Cargo	2006		2007		2008		2009		2010	
	No. Of Ships	**Volumes**	**No. Of Ships**	**Volumes**	**No. Of Ships**	**Volumes**	**No. Of Ships**	**Volumes**	**No. Of Ships**	**Volumes**
General cargo	1609	3373	1477	4199	1148	3417	1410	2277	1283	3105
Containers	875	1520	988	1551	1220	2285	1233	2202	1289	1879

Source: DPA, 2011.

As discussed earlier, the port authority and managers take decisions based on how many ships call at the port and how many tonnes are handled in the port, as mentioned in Table 4.5. Following the traditional approach of measurement, Damietta port performance is evaluated relative to its performance by comparing its actual throughputs over time in terms of tonnage and number of container (Talley, 2007). It can be concluded that the port's managers apply a single-port approach and interviews with the port's operations managers addressed the following problems at Damietta port:

1. High berths occupancy that leads to traffic congestion and lower berth productivity.
2. Low handling rates at different terminals.
3. Improper handling methods, particularly in the general cargo berths.
4. Poor infrastructure of roads and rails inside the port.
5. Insufficient storage areas.

4.9 Chapter Summary

Currently, DPA applies certain indicators and measures for evaluating port performance. Current measures are useful in measuring containerisation and container terminal, but, it does not reflect performances of other terminals where TEU's are not relevant. Also, the performance measurement of other terminals and cargoes is monitored by the total number of ships and the tonnage of cargo handled. Since the main assets of the port are its berths, DPA measures the performance of the berths in terms of the throughput handled per berth; berth occupancy. Many operations have been ignored in current measurement approach, such as berthing time, un-berthing time and standing time.

Two key indicators have received greater attention by the port managers, with no regard to the measures and predictor variables that influence the port. These two indicators are: the number of ships and total tonnes handled. Therefore, the current measurement approach is inefficient as it does not provide feedback about weaknesses at the port, nor does it determine port performance.

Chapter Five

A Quantitative Approach towards Developing DAPEMS

5.1. Introduction

Ports have many clients, including importers, exporters, freight forwarders, stevedoring companies, ships, shipping lines and ship owners. Nowadays, international competition between seaports is based on clients' satisfaction and on meeting their expectations.

Port clients expect to receive high quality service standards in terms of reduced operating expenses, reduced ship turn-around time in ports and at berths and the provision of reliable and proper cargo handling equipment. They also prefer ports with available and appropriately sized storage areas, appropriate facilities and reliable transportation infrastructure. Ports and their clients aim to reduce the total time that cargo stays at the port.

In terms of the provision of these requirements, port managers and authorities face a challenging task to fulfil their clients' needs. They 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.

Previously, the literature review showed that current performance measurement systems applied in ports only partially reflect port performance. Most systems are inconsistent, inaccurate, and unreliable, and some are not easy to use. This is due to an emphasis on containerisation. Current systems focus on measuring container ports, container terminals, or containerised cargoes, with no regard to other types of cargoes handled at ports (Estache et al., 2001; Itoh, 2002; Cullinane et al., 2002; 2004).

Current systems represent the performance of specific terminals rather than the performance of ports. In addition, current measurement systems in ports consider cargo handling as the main activity (Jara-Diaz et al., 2008), with little regard to other activities which play an important role in the port operations, such as storing, the waiting time factor, and loading and discharging rates of cargo handling equipment. Considering the external factors, there is a deficiency in current measurement systems towards the land-side operations. For internal factors, ship turn-around time, berth occupancy and dwell times have not been considered in most systems (Ng, 2005).

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 system aims to provide a high level of visibility of port performances, and to predict future port performance.

This chapter is divided into three stages. Figure 5.1 shows that the first stage starts with the determinants that should be taken into consideration. The second stage discusses how DAPEMS is developed using multiple regression analysis. The third stage formulates DAPEMS using time measures.

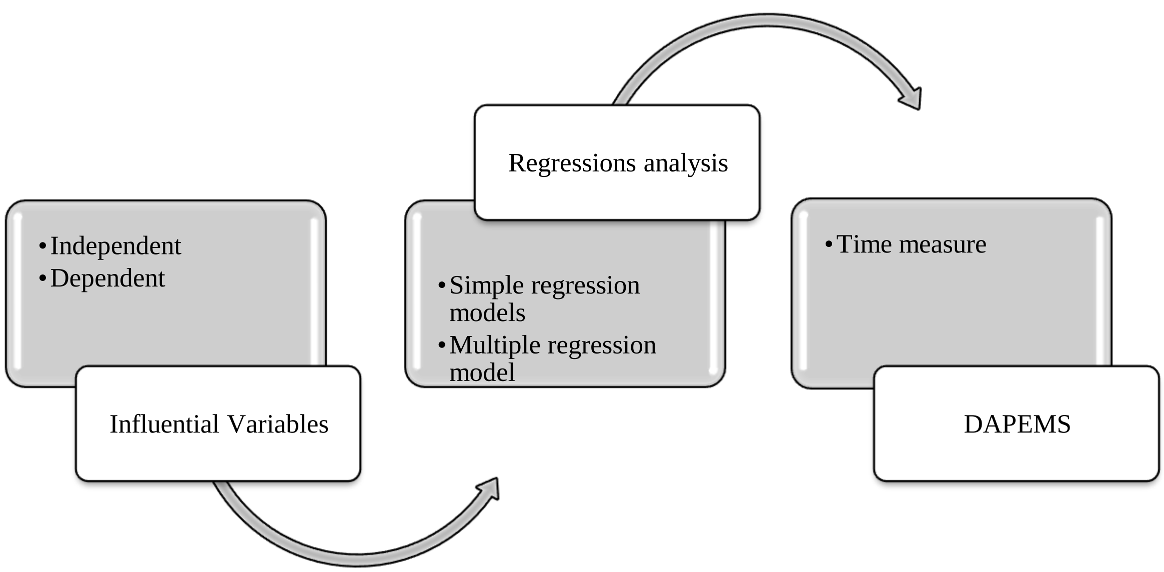


Figure 5.1 -Stages of Developing a More Effective Measurement System

5.2. Determinants of DAPEMS

The capability of DAPEMS can be determined by which measures the system relates to. A single performance measure category is unsatisfactory because it does not cover all aspects of the port operations. Neely and Adams (2002) argued that no single performance measure can truly reflect business performance, because business performance is in itself a multi-faceted concept. In the following part, DAPEMS will be developed using time measures only. The system will be extended to use other measures such as revenue measures (see Chapter Six). The following time based determinants are considered relevant when building a more effective performance measurement system:

5.2.1 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. It is essential to meet the requirements of ship owners, shipping lines and shippers in terms of reducing ship turn-around time (Tongzon et al., 2009), and those of port managers in terms of reducing the total time cargoes remain in the port. 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. In fact, shippers pay indirect logistics costs related to excessive storage cost and port clients are dissatisfied with longer dwelling times. UNCTAD (1976) recommended calculating a ship turn-around time on a monthly basis for each type of cargo. This can be used for measuring the intensity of working at different terminals. Branch (1997) argued that minimising the time a ship spends in port leads to the best use of berths, equipment and maximising throughput at the berths. He also argued that reducing a ship turn-around time helps the ship owners to convey the same volume of cargo using fewer ships.

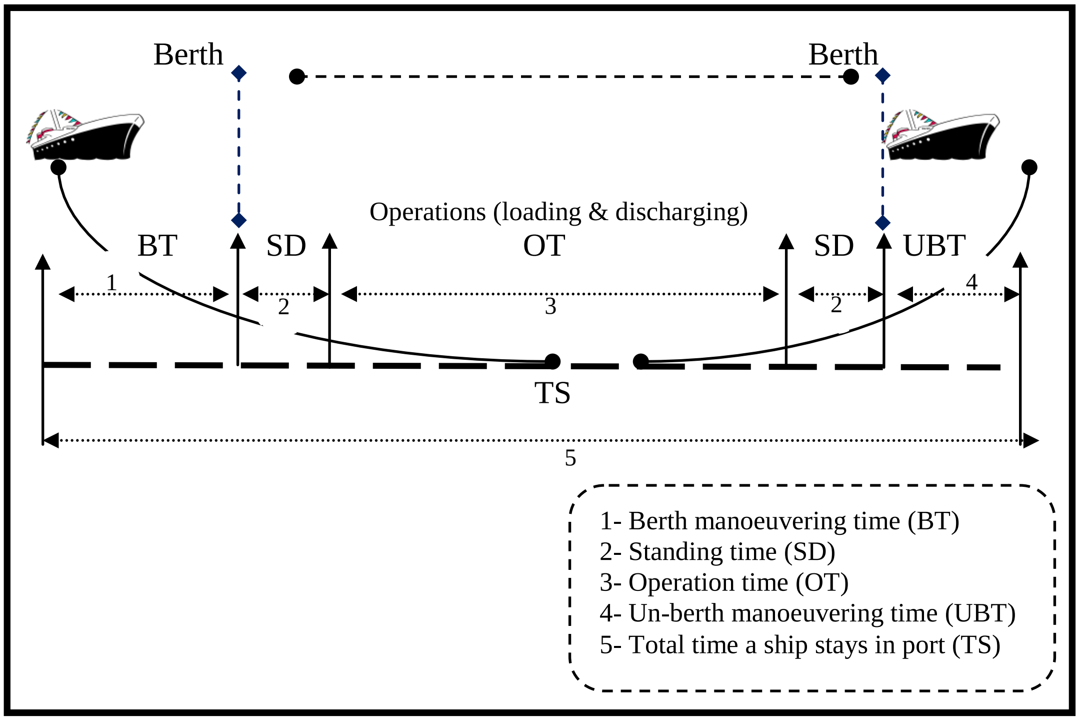


Figure 5.2 -Ship Turn-around Time in Damietta Port

Figure 5.2 shows that the ship turn-around time is divided into five stages as follows:

1. Refers to the elapsed time starting from when a ship enters a port (a ship is in port but not berthing yet) till berthing (BT).
2. Refers to the elapsed time that a ship spends at berth without works (SD).
3. Refers to the elapsed time required in loading and discharging cargoes (OT)
4. Refers to the elapsed time between ships leaving the berth until being outside port (UBT).
5. Refers to the total elapsed time that a ship stays in port from arrival till departure. It is known as ship turn-around time (TS).

Traditionally, ship turn-around time was expressed in days, it is now commonly expressed in hours. DPA normally compiles statistics that providing monthly turn-around times. A ship's turn-around time, from DPA's perspective, does not mean much, as the length of stay of a ship is influenced by the volume of cargo, the facilities made available and the composition of the cargo itself. Usually, it is used to calculate ship productivity (UNCTAD, 1987). However, the researcher argues 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. Also, it is necessary for any port to break the basic ship turn-around time down for dry bulk ships, liquid bulk ships, container ships and general cargo ships. The longer a ship stays in the port, the greater the cost for ship owners, shippers and port clients. The total turn-around time can be used as a measure of a port’s performance (UNCTAD, 1985).

5.2.2. Grouping Port Operations

Port operations have been grouped by the researcher into five groups. Figure 5.3 shows the main operations in ports. The groups of activities are as follows:

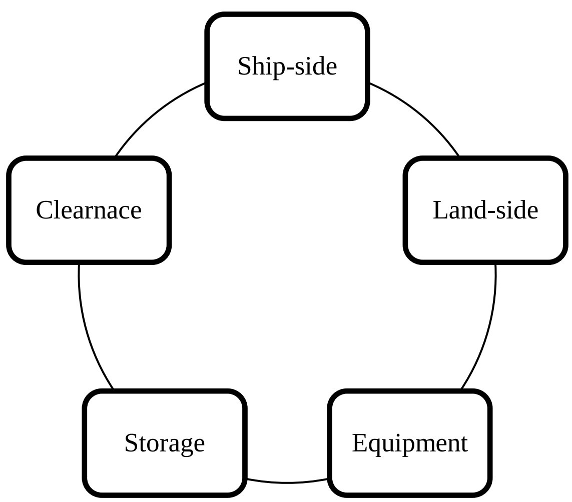


Figure 5.3- Grouping Port Operations

1. Ship-side activities, which involve loading and discharging rates per day, berth occupancy, waiting time at berth and number of calls.
2. Land-side operations, which involve distance between berths and warehouses or port gates and in-port transportation.
3. Equipment operations, which involve the amount of available equipment, their capacities and efficiency.
4. Storage operations, which involve types and number of warehouses and their storage capacities.
5. Clearance activities, which refer to the required time to accomplish the required documentation and clearance.

5.2.3 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. Jara-Diaz et al. (2006) claimed that the most widely accepted classification of cargo is into liquid bulk, solid bulk and general bulk, including containerised general cargo and non-containerised general cargo. Damietta port handles four types of cargoes, namely: general cargo, dry bulk, liquid bulk, and containers. The port dedicates terminals and berths for each type of cargo.

5.2.4. Dwelling Times in Ports

Dwelling time refers to the time that cargoes remain in a terminal's in-transit storage area while awaiting shipment by clearance transportation. Figure 5.4 indicates some of the dwelling times affecting the total time cargoes stay in the port including transport, equipment and storage dwelling times. Longer cargo dwelling times lead to customer dissatisfaction. This could be due to inadequate port capacity, limited cargo handling facilities, shortage of storage areas and low labour productivity.

More importantly, the port authorities are responsible for certain periods of dwelling time until loading and off-loading operations are completed, while the remaining time is due to other stakeholders such as shipping agents, customs, clearing agents, transporters and others responsible for pre- and post-shipment activities. A highly skilled labour force, the availability of sufficient space for storage and proper facilities for quick evacuation of cargoes lead to shorter dwell times in ports. The longer the dwell time the lower the efficiency.

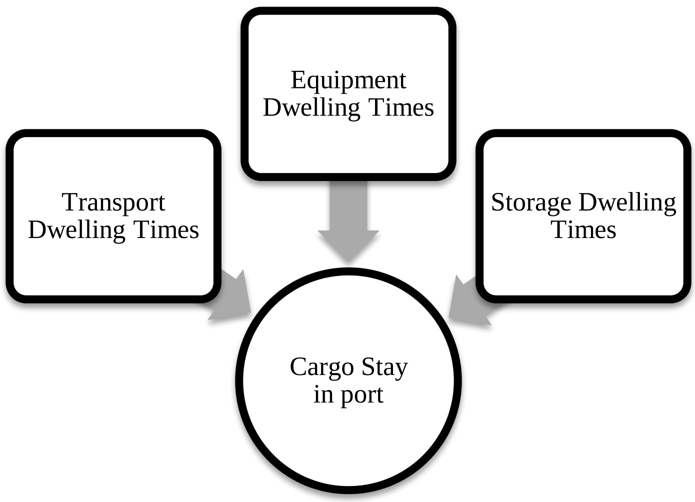


Figure 5.4- Different Dwelling Times

Dwelling time is relatively excessive in Egyptian maritime ports and adds considerable expense to cargo owners. The average dwell time, according to Maersk's statistics, is 21 days in the three main commercial ports: Alexandria, El-Dekheila and Damietta. On the other hand, the Ministry of Transport (2005) reported that the average dwell time in Egypt's main ports is 3.6 days whereas recent studies assert that the dwell time in El-Sokhna port is four to five days compared to an average of 20 days in other Egyptian ports (Mobarek, 2007). There are some discrepancies between dwelling times published by shipping companies, port administration, Egyptian Ministry of Transport and private port operators in Egypt, but, all participants agree that clearance time is the main reason for increasing dwelling times in ports.

This discrepancy appears because dwelling time by shipping companies is calculated taking into consideration how many ships are operated by a company with no regards to other ships operated by other companies. For the port authorities, dwelling time is calculated considering all ships calling at a port with no regards to how many ships are operated by shipping companies. In other words, dwell time is calculated according to the total number of ships calling at a port. For the Ministry of Transport, dwelling time is calculated according to how many ships call at all Egyptian ports.

The port managers claim that the length of dwell times is attributed to importers and brokers failing to file declarations and clearance documents in a timely fashion. Other managers refer to long customs processing or quality control inspections. Table 5.1 illustrates how the length of dwell time influences port performance. The best practice in Table 5.1 was set according to Sokhna Port.

Table 5.1 -Dwelling Times at Egyptian Ports

Indicator	Best Practice	Egyptian Ports
Dwell time (general cargo)	7-12 days	5-20 days
Dwell time (containers)	4-7 days	5-20 days

Sources : Al Tony, 2005

- *Transport dwelling times*

Yard capacity is the main bottleneck in the terminal capacity in ports. Transport dwell time was found to be one of the main variables that influence yard capacity. Usually, supply chain features influence transport dwell time in terms of the poor planning of inland transport, customs blockage and being rolled over due to an over-booked ship. The availability and provision of transport fleets by shippers and shipping agents also influence transport dwell time in ports. The time cargoes remain in a terminal's in-transit storage area is correlated with clearance transportation.

- *Equipment Dwelling Times*

Improving the efficiency of cargo handling equipment can reduce ship turn-around time. Port managers need to know how extensively and intensively its assets are being utilised as well as how well the operations perform financially. Key indicators are determined in relation to the availability of equipment, their capacity and efficiency. Factors affecting the slow evacuation of cargoes from the areas leased and licensed to users include a delay in preparation of documents, mismatch at transfer points, procedural formalities of regulatory authorities, plants and drugs at the port, limited working hours of Customs and other government agencies. All could contribute to longer dwelling times.

- *Storage Dwelling Times*

Competition between ports and shipping lines takes many forms. Giving free time or increasing storage density are the most common forms. It is essential to evaluate the effect of storage dwell time and storage policies on storage density. Also, shipping lines prefer to reduce the duration of storage dwell time given to exporters and importers. As a storage strategy, some cargo owners or receivers opt for cheap storage in port instead of storage at their own warehouses. Thus, port managers should consider which storage strategy is being applied by port clients (Rodrigue and Notteboom, 2009).

It can be concluded that the following determinants have been considered in DAPEMS:

1. A ship turn-around time that refers to how long a ship stays in port
2. Port operations such as number of calls and handling rates. Predictor variables have been selected to represent all groups of operations as detailed in Figure 5.3. A satisfactory discussion with the port managers helped to identify those predictors that influence Damietta port performance and that meet the port strategy (see Chapter Four).

3. Four types of cargoes: general cargo, containers, dry bulk and liquid bulk have been considered.
4. Dwelling times include:
    - Equipment capacity that could lead to equipment dwelling time
    - Storage capacity that could lead to storage dwelling time
    - Transport fleet availability that could refer to transport dwelling time

5.3 Formulation of DAPEMS: steps and structure

Performance measurement systems can be developed using many different techniques such as econometric models, engineering techniques and simulation. Developing DAPEMS requires defining, understanding and implementing steps toward structuring the required system. 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. The next step is to identify those measures and predictors that should be used within the system, and to understand the correlation of the relationships between those predictors. The third step is to structure the system to be compatible with the operating environment (Neely, 1995).

As discussed in Chapter Three, Section 3.5, most measurement frameworks start with defining the strategy and success factors. In the next stage, a selection of the most appropriate measures takes place with defined priorities. This facilitates auditing the current performance measurement system at Damietta port to identify which existing measures will be kept. Finally, each measure is described by predictor variables. Tangen (2004) claimed that this process can be used to design a new performance measurement system, or to enhance an existing measurement system.

In this research, regression analysis has been applied as a method for explanation of phenomena and prediction of Damietta port performance. A coefficient of correlation - *r*- between the dependent and predictor variables is a quantitative index of association between those variables (Kleinbaum et al., 2008). In regressions, Y refers to the response variable, while, the set of predictor variables are used to explain the variability of the criterion variable. At the outset, 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). In Chapter Four, Damietta port's strategy focuses on the port's capability to compete with other ports through improving performance. Interviews with the port director and the port managers explained the strategy in terms of 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. Jara-Diaz et al. (2006) claimed that any port aims to increase its productivity and reduce the cost of its operations through the time of the operation, the cost of time and the monetary tariffs.

Talley (2007) claimed that a port can reduce time-related costs by reducing the time cargo stays in port. He argued that when a port's actual throughput approaches its optimum throughput, a port's performance has improved. An engineering optimum throughput is used in an environment in which a port is not in competition with other ports, while an economic optimum throughput is used in a competitive environment. Engineering optimum throughput refers to the maximum throughput that a port can physically handle (a port's capacity), and the economic optimum throughput is defined as the port's ability to achieve its economic objective or objectives.

In addition, Brooks and Cullinane (2007) recommended further research for developing instruments to measure port performance, which should be derived from the port strategy and objectives. As a public port, Damietta port's strategy has been set by the government, which is related to both the port’s internal needs and the government’s objectives. Hence, the response variable in DAPEMS is the total time cargo remains in port. Azzone et al. (1991) discussed the impact of time, as a fourth dimension of competition alongside cost, quality and innovation, on values through two ways: directly through higher market share and responsiveness, and indirectly through the widespread improvement of efficiency and productivity. Thus, time affects the competitive position of a firm.

Talley (2006b) argued that ports provide different quality of services to their clients in terms of the speed of movement, which is affected by ship loading and unloading service rates and by the average ship arrival and departure waiting times. He developed a function to calculate the annual total time in a port that is expressed by:

1. average ship loading rate
2. average ship unloading rate
3. average arrival waiting time
4. average departure waiting time
5. port channel accessibility
6. port berth accessibility
7. port channel reliability
8. port berth reliability
9. port channel variability
10. average arrival rate
11. average service rate

Talley explained that the total time of cargo in a port is the sum of the time it is aboard a ship in port, the time it is aboard a vehicle in port, the time it is in storage in port, and the transit time when it moves from and to storage in a port. He focused on the port time as one of the main components of the economic theory of ports. A recommendation was made to estimate and investigate the effects of time on ships, cargo and vehicles. Figure 5.5 illustrates the assumptions of DAPEMS. Reducing the total time cargo remains in the port will improve port performance and increase the port clients' satisfaction. Port clients wish to receive their cargo in the shortest possible time. For port managers, the 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. 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.

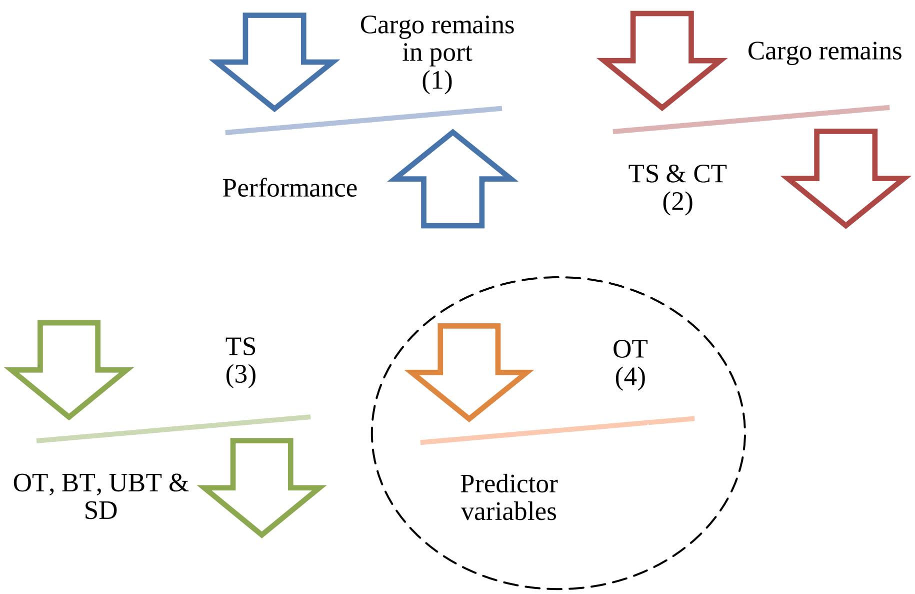


Figure 5.5- Assumptions of DAPEMS

For determining the predictor variables, two questions need to be addressed, as they help identify the rest of the assumptions of DAPEMS:

1. Question One: What are the predictor variables that influence the total time cargo remains in port?
2. Question Two: 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) as shown in Figure 5.5. TS refers to the total time between a ship's arrival in a port to its departure. It includes ship turn-around time. CT refers to the procedures involved in getting cargo released. It involves a series of procedures such as payment, submission of documentations and bill of lading.

For TS, Figure 5.5 corroborated that berthing time (BT), un-berthing time (UBT), standing time (SD) and operation time (OT) influence TS in the port, as in the equation (1):

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

DPA has provided data for BT, UBT, and SD variables. The problem existed in getting data about OT. OT refers to the total time required for loading and discharging cargo at berth. Currently, there is no formal recording of operation time in Damietta port (See Chapter Four). Interviews with the port's technical office and the port director showed that a private company (DCHC) is responsible for loading and discharging cargoes and it keeps its own records. Providing data about operation time (OT) was not accessible, nor allowed either for this research or was it provided for the port managers. An interview was arranged with the operations manager at DCHC but this was not positive in providing the required data. Hence, regression analysis was performed to calculate OT (See 5.3.2).

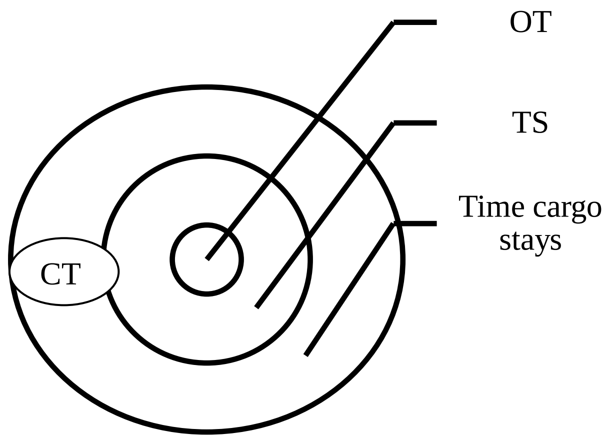


Figure 5.6- Interrelated Variables Influence the Time Cargo Stays in Port

For the second question, the researcher assumed as shown in Figure 5.6 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 that the remaining assumptions incorporated are as follows:

1. Reducing the total time cargo stays in the port will improve port performance.
2. Reducing TS and CT should minimise the total time cargo remains in a port.
3. OT, BT, UBT, and SD are parts of TS.
4. There are key predictors that influence OT.
5. Ordinary Least Square (OLS) regression analysis has been applied in calculating OT.
6. It is important to calculate separately the effects of operation time OT and the total time a ship stays in port TS.
7. Two variables have constant values according to the available data in Damietta port. These are equipment and in-port transportation.
8. It is assumed that the port does not operate its facilities at the 100% utilisation rate.
9. The Egyptian Ministry of Transport has set constant values for all fees, dues and associated costs. These values are applied in all Egyptian ports.
10. Number of working hours per shift is constant.

5.3.1 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. Data were not available for OT in Damietta port, nor recorded by the port managers. Hence, calculating OT is required for calculating TS. As mentioned above, improving (TS), through improving (OT) and reducing (CT), will lead to a reduction in the total time cargo remains in the port. OT, CT and TS can be used by the port managers to indicate whether the port performance is improving or weakening.

5.3.2 OT Calculation

Regression analysis has been applied to determine OT. It examines the relationship and causes and effects between OT and key performance variables. Table 5.2 shows that there are seven important variables influencing OT: the number of calls, total tonnes handled (total imports and exports), berth occupancy, loading and discharging rates per day, storage yards, equipment efficiency, and in-port transportation. With regards to the available data in Damietta port, two variables were excluded as they are constant values. These are equipment and in-port transportation variables. Data were collected for four types of cargoes, including general cargo, dry bulk, liquid bulk and containers, to cover all these variables (See Appendix I). 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. Fourthly, these variables present the main problems facing Damietta port as stated in Section 4.8.

For the number of calls variable, UNCTAD (1976) argued that this variable is a good indicator to determine port efficiency as it affects the quantity of cargo carried by ships. It recommended using this variable to determine the quality of services provided at ports. Also, the number of calls can be used as a criterion for selecting a port (Tongzon, 1995), and it can be used for measuring port performance (Tongzon et al., 2009). For the total tonnes handled variable, Talley (2007) claimed that total volumes handled can affect the total time cargo remains in a port and port performance (Tongzon et al., 2009).

For the berth occupancy variable, De and Ghosh (2003) used berth occupancy as an indicator to represent port efficiency (Yeo et al., 2011). For the handling rate variable, Chung (1993) discussed that loading and discharging rates influence a ship's turn-around time. It is an important variable as it reflects the handling equipment available. For the storage yard variable, UNCTAD (2004) focused on port landside in port performance measurement, including storage and warehousing sites. It considered storage as one of the main functions of a port to satisfy clients through keeping cargo for shorter periods.

For the equipment productivity variable, Wang et al. (2003) used the amount of equipment as an input to determine a port's production. They used only the number of equipment available and their capacities as an input to determine port productivity. Equipment is considered as those cargo-related facilities required to transfer cargo in ports. Tongzon (2001) argued that handling equipment is important to facilitate port operations. For the in-port transportation variable, Vanags (2004) claimed that this variable influences cargo turnover in a port. Thus, it is an important indicator used by importers and exporters to select calling ports.

The criteria used for variables selection were:

1. Data availability at Damietta port. As discussed in Chapter Three, data were collected in interviews undertaken with the port managers involved in the management of the performance measurement. Also, interviews were undertaken with managers from a variety of functions within Damietta port to obtain a broad view of performance measurement systems.
2. Other variables, which have not been used, measure the same things as the variables used, such as frequency of calls, berth throughput, vessel's stay and volume of cargo.
3. These variables have been selected to represent the five groups of port operations that have been discussed earlier.
4. Variables have been selected to meet the port managers' needs (see Appendix H). Interviews and discussion with the port operations manager and the technical office manager have been organised and used for this purpose.
5. Variables have been selected to achieve the port strategy that aims to improve port performance through minimising the total time cargo remains in the port. The interview with the port director has been held to explain the strategic objectives of Damietta port.

Table 5.2 – 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	No .of calls	Independent
TTH	Total tonnes handled	Independent
BO	Berth occupancy	Independent
LDR	Loading/discharging rates	Independent
ST	Storage	Independent

5.3.3 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 into MINITAB 15.1.13 software. No calculations will be carried out to calculate CT. Available data have been approved and verified by the MOT and custom association to ensure data reliability. This is the only way to check the reliability of available data as there are strict rules for those non-staff to be involved in monitoring and collecting data about clearance. Ghoneim and Helmy (2008) claimed that clearance time has recently improved in Egyptian ports because of automation, reducing the number of signatures required and strict inspection processes.

5.4. Simple and Multiple Regressions Analysis

Regression analysis is a statistical tool applied to develop DAPEMS. It helps to determine how OT changes as predictor variables change, and to predict the value of OT. It is important to answer two questions about the contribution of predictor variables to the prediction of OT:

1. Does the entire set of predictor variables contribute significantly to the prediction of OT? (An overall test)
2. Does the addition of one predictor variable add significantly to the prediction of OT? (test for addition a single variable)

In order to answer these questions, it becomes important to determine the best-fitting model for describing the relationship between OT and other predictor variables. Best model means a reliable model that gives the best prediction of OT. There are some steps that have to be followed in selecting the best regression model (Kleinbaum et al., 2008):

1. Establishing separate simple regression models between OT and the predictor variables.
2. Establishing multiple regression models.
3. Evaluating the reliability of the model chosen.

Many simple and multiple regression models have been performed separately. The aim is to find the best fitting models. The following procedures have been applied to get the best fitting models:

1. To find the optimal values for the coefficients in each regression function, as coefficients represent the estimated change in OT for each unit change in the predictor value. It helps also to determine how well the estimated line fits the data.
2. To identify the coefficient p-values. The coefficient value for p proves whether the association between the response and predictors is statistically significant, or not.
3. To compare the coefficient p-values to a-level. If the p-value is smaller than the a-level, the association is statistically significant. A commonly used a-level is 0.05. This value indicates that there is sufficient evidence that the coefficients are not zero.
4. The square root of the mean square error (S) and coefficient of determination (R^2) are measures of how well the model fits the data. These values can help to select the model with the best fit. The S provides a measure of how spread out the data are. The R^2 value is the proportion of variability in the Y variable (response) accounted for by the predictors (Taylor, 2007).
5. Adjusted square root will be observed.
6. The scatter diagrams describe the strength of the relationship between two sets of variables.
7. Pearson's r can be any value from -1.00 to +1.00. The higher the absolute value, the stronger the relationship, be it negative or positive (Taylor, 2007).

8. A multicollinearity test was carried out to ensure that there is no exact linear relationship between the predictors. A variance Inflation Factor (VIF) test will be performed as a measure of how multicollinearity affects associated with each predictor. It is used to detect whether one predictor has a strong linear association with the remaining predictors.

It measures how much the variance of an estimated regression coefficient increases if predictors are correlated as follows (Montgomery and Peck, 1982):

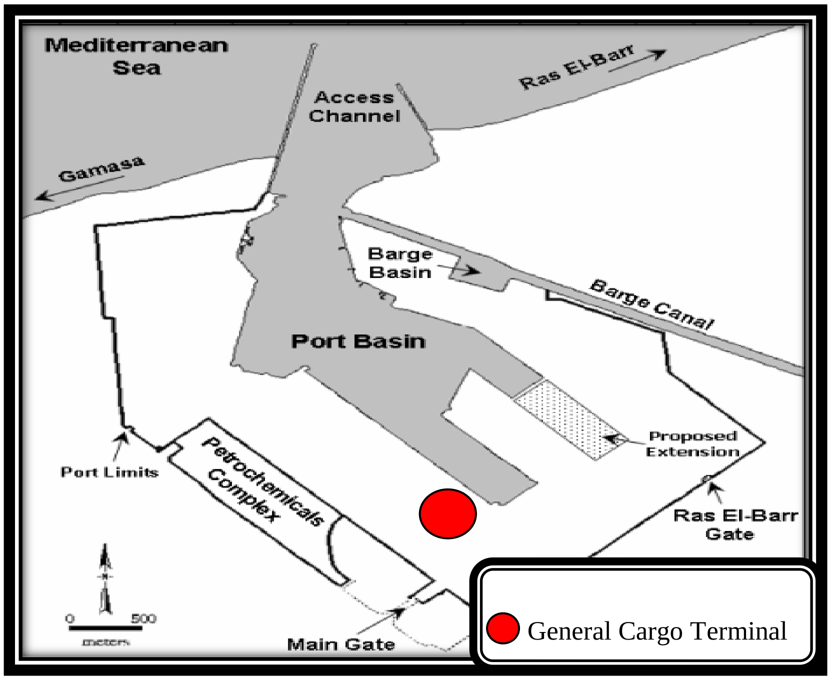
VIF < 5 = normal relation; VIF between 5 and 10 = milled relation; VIF > 10 = perfect relation

9. Stepwise regressions are applied to test for errors in models that will be selected by OLS regressions. This takes place by using a sample of available data to build a model and then uses the rest of the available data to test the accuracy of the model.
10. Best subset regressions aim to test all possible sets of predictors and select the best set that provides best fitting models.

In the following part, regression analysis has been applied to calculate OT at different terminals in Damietta port including: general cargo terminal, dry bulk terminal, liquid bulk terminal and container terminal.

5.4.1 General Cargo Regression Analysis

At any terminal, there are three elements normally considered for improving terminal performance (UNCTAD, 1978). The first element is the **productivity**. It is normally defined as the total tonnes of general cargo handled in the port. The second element is the **interruptions** which tend to happen. It affects ship output, terminal productivity and the port performance. The third element is the **equipment** used in handling.



5.7- General Cargo Terminal

Figure 5.7 shows the location of the general cargo terminal at Damietta port that includes four general cargo berths (berths no. 5, 6, 7, and 8) with 800 metres length and 12 metres depth. Also, the terminal is provided with a general cargo yard of 500,000 m^2. It handles exports of agricultural products, fertilisers and furniture and receipt of imported goods such as petrochemicals, grains and flour. The terminal handles a total capacity of 2.1 million tonnes annually.

Many simple and multiple regression models have been performed using Ordinary Least Square (OLS)[1] regressions to examine the significance of relationship between OT as a response variable and other predictor variables that are stated in Table 5.2. In all simple models, the Pearson's R is not zero. This means that there is definitely a relationship between OT and predictor variables.

[1] OLS is beneficial as it minimises the sum of squared residuals. It helps to provide un-biasedness and consistency estimation because it estimates change in entirely expected ways when the units of measurement of the response and predictors change (Wooldridge, 2005, p.30).

However, any relationship between OT and predictors is not necessarily statistically significant. In order to determine whether the observed relationship between the response and predictors is significant, the significance level was tested through:

1. The coefficient of p-values, as it explains whether or not the relationship between the response and predictors is significant.
2. Comparing the coefficient p-values to α- level, as if the p-value is smaller that α-level, the relationship is statistically significant. A commonly used α- level is 0.05.

Firstly, many simple regression models have been performed where OT_{gen} is the response variable (See Appendix D). There were regression models that have been ignored from the results as the predictors have no influence on OT_{gen}. Equation (2) shows one of the simple regression models that has not been selected, such as OT_{gen} versus BO.

$$\mathbf{OT = 2962 + 13.3\ BO} \qquad (2)$$

```
Predictor   Coef  SE Coef     T      P
Constant    2962     2842  1.04  0.302
BO         13.29    35.46  0.37  0.709


S = 1054.01   R-Sq = 0.2%   R-Sq(adj) = 0.0%
```

This example shows a very weak relationship between OT_{gen} and BO. R-sq is weak and the p-value indicates that the relationship between OT_{gen} and BO is not significant. S=1054.01, which is considered high as the estimated standard deviation about the regression line.

Secondly, multiple regressions have been performed to identify the best fitting model. The purpose is to examine whether OT_{gen} can be predicted by NCS, TTH, BO, LDR and ST variables.

The outputs found that the best three-predictor model estimates OT_{gen} from NCS, ST and BO. Equation (3) displays the best regression model for general cargo.

$$\mathbf{OT_{gen} = -2054 + 47.8\ NCS + 0.00468\ ST + 28.5\ BO} \qquad (3)$$

Predictor	Coef	SE Coef	T	P
Constant	-2054.1	568.2	-3.62	0.001
NCS	47.789	2.320	20.59	0.000
ST	0.004676	0.002117	2.21	0.031
BO	28.475	7.333	3.88	0.000

S = 325.9   R-Sq = 90.8%   R-Sq(adj) = 90.3%

The interpretation of the regression equation follows:

1. The slope (b1 = 47.8) is the change in OT_{gen} when NCS increases by 1. That is, when the NCS increases by one unit, the OT_{gen} increases by 47.8 units.
2. The slope (b2 = 0.00468) is the change in OT_{gen} when ST increases by 1. That is, when the ST increases by one unit, the OT_{gen} increases by 0.00468 units.
3. The slope (b3 = 28.5) is the change in OT_{gen} when BO increases by 1. That is, when BO increases by one unit, the OT_{gen} increases by 28.5 units.
4. The constant (intercept) value (bo = - 2054) is the predicted value of OT_{gen} when each predictor (NCS, ST and BO) is zero. That is, when the predictors are zero the OT_{gen} is - 2054.

The goodness-of-fit measure is not only to focus on the adjusted R squared. Adding more predictors may not enhance the prediction of OT_{gen}, but it inflates the R square. Adding more variables to the model caused R squared to increase a little (Wooldridge, 2005). Hence, it was found out that TTH and LDR have no significant relationship with OT_{gen}.

When the LDR predictor was introduced to the model, it did not help to account for a significant portion of the remaining variation in OT_{gen}. In addition, 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). Thus, LDR has no significant effect in the model as ST predictor measures the same thing.

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). Therefore, the handling rate appears to be very high as the freight tonnes are measured in cubic meters.

For the TTH predictor, the correlation matrix in Table 5.3 indicates that there is a significant relationship between OT_{gen} and TTH, as it accounted for 95%. However, 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 if multicollinearity is present (Draper and Smith, 1998). Higher correlation is called exact dependency or exact multicollinearity. Hence, TTH predictor has been excluded to avoid multicollinearity. Also, VIF test shows that TTH's VIF equals 5, which leads to poor estimation. It is important to highlight that the correlation matrix can be used to measure if the multicollinearity exists (Belsley, 1991).

Table 5.3- Correlations: OT_{gen}, NCS, BO, ST, LDR, TTH

	OT	NCS	BO	ST	LDR
NCS	0.935 0.000				
BO	0.446 0.000	0.311 0.015			
ST	0.140 0.288	0.044 0.739	0.068 0.608		
LDR	-0.118 0.371	-0.084 0.521	-0.005 0.971	-0.100 0.446	
TTH	0.953 0.000	0.891 0.000	0.300 0.020	0.064 0.629	-0.084 0.524

The correlation coefficient calculates the relationship between each pair of predictors and the response. It measures the degree of linear relationship between variables. The correlation coefficient assumes a value between -1 and +1. The usefulness of correlation is to examine two things about the linear relationships between OT_{gen} and the predictors: it examines the strength of the linear relationship between the variables, and it examines the direction of the sign of the coefficient which indicates the direction of the relationship, either positive or negative. Table 5.3 shows the correlation matrix for general cargo and can be interpreted as follows:

1. It shows that NCS, ST, BO and TTH have positive effects on OT_{gen} and on each other, except LDR where the correlation coefficient is negative.
2. This means that when NCS, ST, BO and TTH increase, OT_{gen} also tends to increase.
3. The correlation between OT_{gen} and TTH has the strongest relationship that accounted for 95%, followed by NCS that accounted for 93%.
4. The correlation between OT_{gen} and BO has a moderate relationship that accounted for 44%.
5. There is a strong relationship between NCS at Damietta port and TTH that accounts for 89%, which is considered as multicollinearity (Draper and Smith, 1998).

The following figures display the residual plots that can be used to examine the goodness of fit of the model:

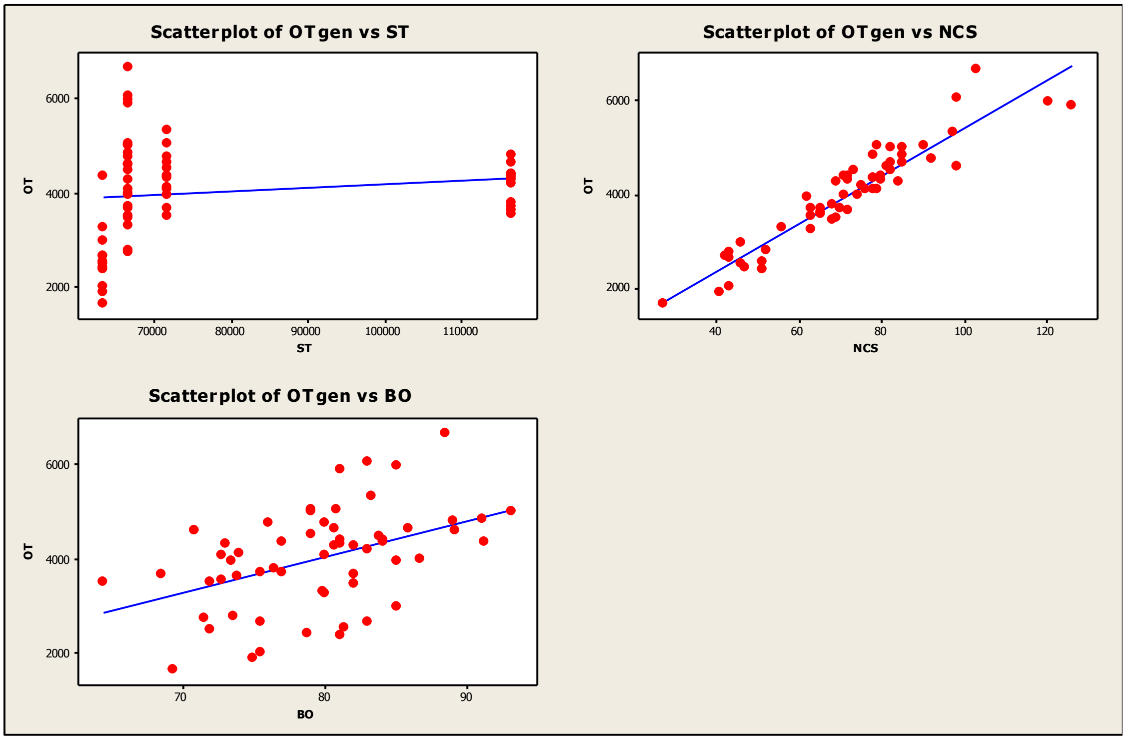


Figure 5.8 - Scatter Plot of OT_{gen} vs. NCS, ST, BO

Figure 5.8 displays the scatter plot to show the relationship between OT_{gen} and each predictor. It is found that all the predictors positively affect OT_{gen}. The figure shows that:

1. As expected, there is a strong relationship between OT_{gen} and NCS. An increase in the number of ships calling at Damietta port will result in increased total operation time.
2. For the ST predictor, the scatter plot shows how ST meets $OT_{gen.}$ The problem is that the port has expanded the storage areas for general cargo.
3. For the BO predictor, there is obviously a lot of variability. This is because higher berth occupancy does not necessarily mean higher operation time. The general cargo berths may be occupied with ships whilst there are no loading and discharging operations.

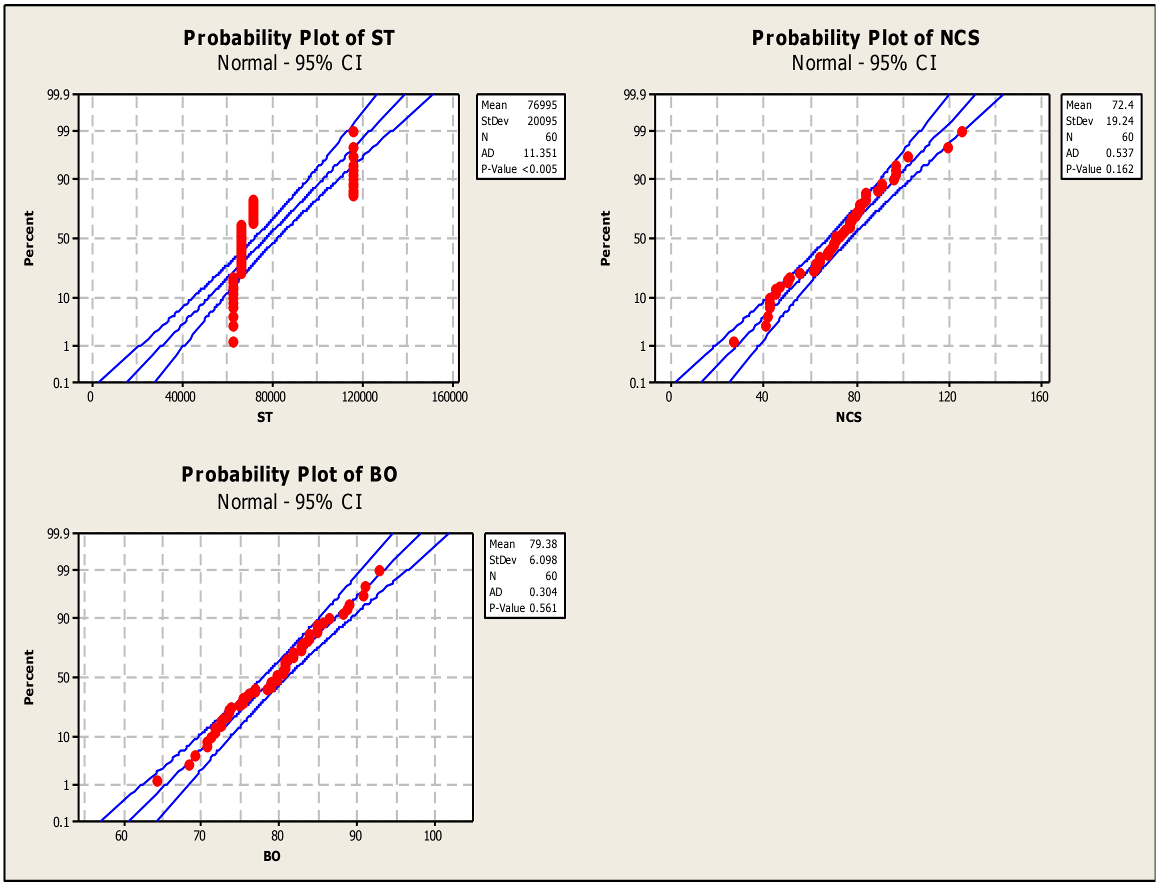


Figure 5.9- Probability Plot of NCS, ST and BO

Figure 5.9 shows that the points generally form a straight line in both NCS and BO predictors. This means that the normality assumption is valid in these predictors. Some observations have moderate departures from normality, but it does not seriously affect the results.

For the ST probability plot, data deviate from a normal distribution, as the points of the graph do not form a straight line. In reality, almost no data are truly normal. It indicates that other variables may influence OT_{gen}, or there are outliers. The reason is that the increase in warehouse storage areas and yards cannot be reduced once they are established, while OT_{gen} is variable.

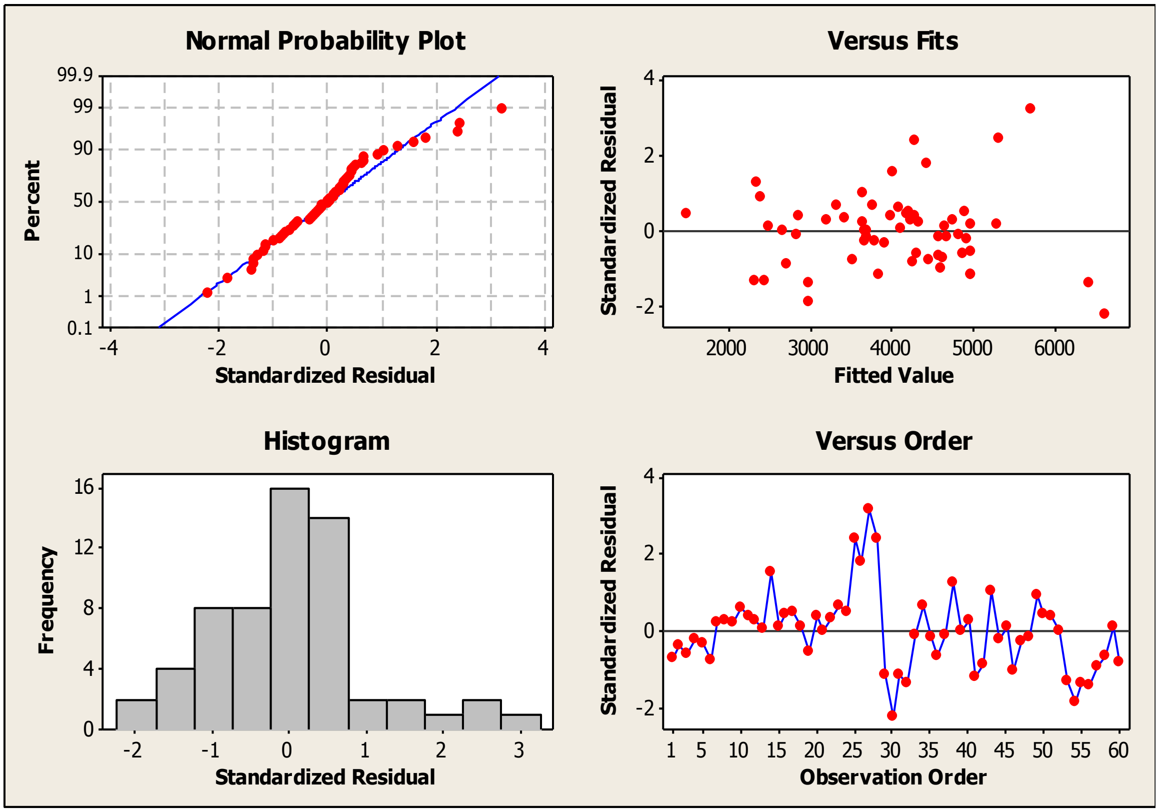


Figure 5.10- Residual plots for OT_{gen}

Figure 5.10 shows the residual plot for $OT_{gen.}$ It displays the following:

1. **Normal probability plot-** It shows that the points generally form a straight line, which means that the residuals are normally distributed.
2. **Residuals versus fits**- It shows 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.
3. **Histogram** - It examines the variation and shape characteristics of the data using a histogram of residuals. The histogram shows that data are normally distributed relatively little skewness. It is slightly positively skewed (right skewed) because the "tail" of the distribution points to the right, and because its skewness value will be greater than 0.

4. **Residuals versus order**- It indicates non-random error. A positive correlation is indicated by a clustering of residuals with the same sign. A negative correlation is indicated by rapid changes in the signs of consecutive residuals. The versus order shows 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.
5. **Stepwise regressions** - Stepwise regression has been performed to find out the best explanation of all testable influences on OT_{gen}. Linear regression models represent the relationship between OT_{gen} and predictors and because interaction increases exponentially with the number of predictor variables, stepwise regressions have been performed to avoid any confusion concerning the identification of significant effects. Also, stepwise regression ensures that adding each predictor contributes to the model and ends up with the smallest possible set of predictors included in the best fitting model.

Table 5.4 displays the stepwise regressions. The results show that the best fitting model to emerge from the stepwise analysis contains four predictors; NCS, TTH, BO and ST, where R-sq increased to 97% and S decreased to 181. However, TTH has been excluded to avoid the multicollinearity as the relationship between TTH and NCS accounted for 89% of the variation.

Table 5.4- Stepwise Regression: OT_{gen} versus NCS, TTH, BO, LDR, ST

Response is OT_{gen} on 5 predictors, with N = 60

Step	1	2	3	4
Constant	859.7	455.7	-1495.2	-1737.2
TTH	0.00810	0.00497	0.00482	0.00475
T-Value	24.02	8.47	10.48	11.23
P-Value	0.000	0.000	0.000	0.000
NCS		22.5	20.7	21.0
T-Value		5.99	6.99	7.72
P-Value		0.000	0.000	0.000
BO			27.0	26.2
T-Value			6.07	6.42
P-Value			0.000	0.000
ST				0.0040
T-Value				3.39
P-Value				0.001
S	319	252	198	181
R-Sq	90.87	94.39	96.62	97.20
R-Sq(adj)	90.71	94.20	96.44	97.00
Mallows Cp	126.2	57.8	15.5	5.8
PRESS	6251499	4070246	2531266	2208191
R-Sq(pred)	90.32	93.70	96.08	96.58

Comparison between the residual plots in Figure 5.10, where TTH has been excluded and the residual plots in Figure 5.11 where TTH has been added, shows that it is obvious that the TTH predictor has contributed in the prediction of OT. The decision was made to remove the TTH predictor to avoid the multicollinearity. Multicollinearity means that there is a strong relationship between the regression exploratory variables, while linear regression analysis assumes that there is no exact relationship among exploratory variables (Bowerman and O'Connell, 1990). As there is a strong relationship between NCS and TTH, the TTH predictor has been excluded not to violate the linear regression assumption.

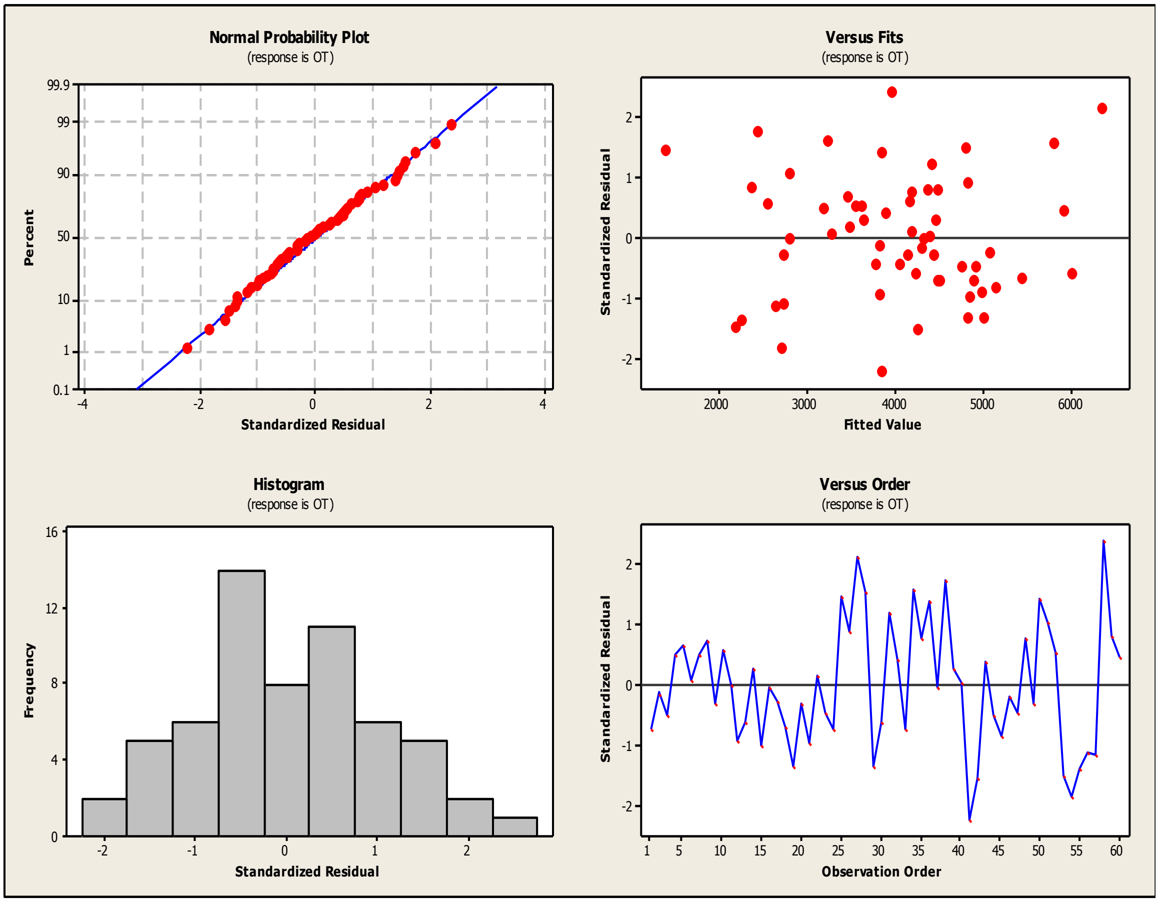


Figure 5.11- Residual plots for OT_{gen}

6. **Best Subsets Regression**- This is used as a method to help determine which predictors should be included in a multiple regression model. This method involves examining all of the models created from all possible combination of predictor variables.

Table 5.5 displays the results of the best subsets regressions. It indicates that there are two best multiple regression models where the TTH predictor is added. However, if multicollinearity exists, it will increase the R-square as well, which will impact on the goodness of fit of the model as in the best subsets regression outputs.

Table 5.5- Best Subsets Regression: OT_{gen} versus NCS, TTH, BO, LDR, ST

Response is OT

Vars	R-Sq	R-Sq(adj)	Mallows Cp	S	NCS	TTH	BO	LDR	ST
1	90.9	90.7	126.2	318.93		X			
1	87.3	87.1	196.5	375.47	X				
2	94.4	94.2	57.8	252.03	X	X			
2	93.7	93.4	72.3	267.81		X	X		
3	96.6	96.4	15.5	197.51	X	X	X		
3	95.1	94.8	45.6	237.56	X	X			X
4	97.2	97.0	5.8	181.25	X	X	X		X
4	96.8	96.5	14.7	195.13	X	X	X	X	
5	97.3	97.0	6.0	179.94	X	X	X	X	X

Equation (4) concludes that the best linear fitting regression model that includes three predictors: NCS, ST and BO predictors. The model is as follows:

$$\mathbf{OT_{gen} = -\,2054 + 47.8\ NCS + 0.00468\ ST + 28.5\ BO} \qquad (4)$$

5.4.2 Dry Bulk Regression Analysis

Figure 5.12 shows that the dry bulk terminal has four berths with 900 metres length and 12 metres deep. The terminal handles dry bulk cargoes such as fertilisers, cement, sand and maize. The terminal received 292 dry bulk ships in the year 2009 and this number has sharply increased to 356 ships in the year 2010 (MTS, 2011). The maximum capacity that the terminal can handle annually is 6.2 million tonnes, and the storage capacity is up to 500,000 tonnes.

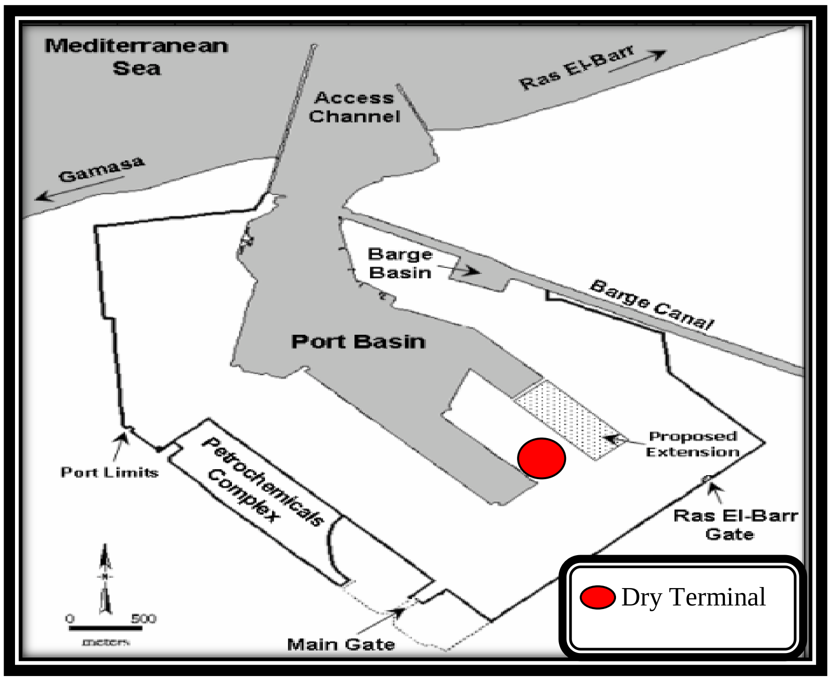


Figure 5.12- Dry Bulk Terminal

Firstly, many simple regression models have been performed where OT_{dr} is the response variable. Poor fitting regression models have been ignored from the results where the predictors have no influence on OT_{dr}. Equation (5) shows one of the simple regression models that has not been selected, (See Appendix E) such as OT_{dr} versus BO, ST, LDR.

$$\mathbf{OT = 833 + 31.3\ BO - 0.0129\ ST + 0.0064\ LDR} \qquad (5)$$

Predictor	Coef	SE Coef	T	P
Constant	833	1511	0.55	0.583
BO	31.29	17.05	1.83	0.072
ST	-0.012886	0.006854	-1.88	0.065
LDR	0.00636	0.01152	0.55	0.583

S = 499.369   R-Sq = 10.6%   R-Sq(adj) = 5.8%

This example shows a very weak relationship between OT_{dr} and BO, ST and LDR. R-sq has accounted about 10%, while the p-value indicates that the association between the response and predictors is statistically not significant. S = 499.369, which is considered high. The weaker the response variable prediction, the higher S is.

Secondly, numerous multiple regression models have been performed to find out the best fitting model. The purpose is to examine whether OT_{dr} can be predicted by NCS, TTH, BO, LDR and ST variables. The outputs found that the best three-predictor model estimating OT_{dr} is NCS, TTH and ST. Equation (6) displays the best regression model for dry bulk cargo.

$$\mathbf{OT_{dr} = -\ 1110 + 51.2\ NCS + 0.00159\ TTH + 0.00622\ ST} \quad (6)$$

Predictor	Coef	SE Coef	T	P
Constant	-1110.3	348.6	-3.18	0.002
NCS	51.170	3.418	14.97	0.000
TTH	0.0015946	0.0004287	3.72	0.000
ST	0.006219	0.002433	2.56	0.013

S = 170.471   R-Sq = 89.6%   R-Sq(adj) = 89.0%

The interpretation of the regression equation follows:

1. The slope (b1 = 51.2) is the change in OT_{dr} when NCS increases by 1. That is, when the NCS increases by one unit, the OT_{dr} increases by 51.2 units.
2. The slope (b2 = 0.00159) is the change in OT_{dr} when TTH increases by 1. That is, when the TTH increases by one unit, the OT_{dr} increases by 0.00159 units.
3. The slope (b3 = 0.00622) is the change in OT_{dr} when ST increases by 1. That is, when ST increases by one unit, the OT_{dr} increases by 0.00622 units.

4. The constant (intercept) value (bo = 1110) is the predicted value of OT_{dr} when each predictor (NCS, TTH and ST) is zero. That is, when the predictors are zero the OT_{dr} is 1110.

It was found that BO and LDR have no significant relationship with OT_{dr}. When these two predictors were introduced to the model, it did not help account for a significant portion of the remaining variation in OT_{dr}.

The BO predictor is not significant because dry bulk cargo is subject to phytosanitary inspections before loading and discharging. The inspections take place twice 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.

The LDR predictor 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.

It is important to state that there are two regression models that have results similar to the best-fitting model which has been selected. Equations (7) and (8) display these regression models. In the first model, LDR has no truly significant influence on $OT_{dr.}$ Also, in the second model, the observed relationship is not statistically significant with BO. This is because of the reasons that have been discussed earlier. Hence, excluding LDR and BO predictors will not greatly affect the change in $OT_{dr.}$

$$OT_{dr} = -1157 + 51.6\ NCS + 0.00151\ TTH + 0.00202\ LDR + 0.00635\ ST \quad (7)$$

Predictor	Coef	SE Coef	T	P
Constant	-1156.5	364.6	-3.17	0.002
NCS	51.587	3.554	14.51	0.000
TTH	0.0015090	0.0004686	3.22	0.002
LDR	0.002020	0.004297	0.47	0.640
ST	0.006353	0.002466	2.58	0.013

S = 171.669   R-Sq = 89.6%   R-Sq(adj) = 88.9%

$$OT_{dr} = -1218 + 51.1\ NCS + 0.00157\ TTH + 1.76\ BO + 0.00602\ ST \quad (8)$$

Predictor	Coef	SE Coef	T	P
Constant	-1217.7	513.2	-2.37	0.021
NCS	51.123	3.450	14.82	0.000
TTH	0.0015675	0.0004425	3.54	0.001
BO	1.762	6.138	0.29	0.775
ST	0.006024	0.002545	2.37	0.021

S = 171.885   R-Sq = 89.6%   R-Sq(adj) = 88.8%

The following correlation matrix indicates that there is a significant relationship between OT_{dr} and NCS 92%, followed by TTH that was 69%. It is observed that the relationship between NCS and TTH is about 62%. As discussed earlier, dry bulk ships stay longer awaiting the results of inspections with no operations being performed. Hence, it was really important to take the TTH predictor to examine how it affects OT_{dr}. The VIF test shows that there is no perfect multicollieanarity between predictors.

Table 5.6- Correlations: OT_{dr}, NCS, TTH, BO, LDR, ST

	OT	NCS	TTH	BO	LDR
NCS	0.929				
	0.000				
TTH	0.692	0.624			
	0.000	0.000			
BO	0.190	0.137	0.211		
	0.145	0.298	0.105		
LDR	0.107	0.045	0.347	-0.039	
	0.418	0.735	0.007	0.766	
ST	-0.218	-0.318	-0.333	0.172	-0.183
	0.095	0.013	0.009	0.190	0.162

The analysis of Table 5.6 is as follows:

1. It shows that NCS, TTH, BO and LDR have positive effects on OT_{dr} and on each other, except ST for which the correlation coefficient is negative.
2. This means that when NCS, TTH, BO and LDR increase, OT_{dr} also tends to increase.
3. The correlation between OT_{dr} and NCS has the strongest relationship that accounted about 92%.
4. There is a moderate correlation between LDR and TTH that accounted for about 34%.
5. There is a negative relation between ST at Damietta port and TTH that accounts for about - 33%.

The following figures display the residual plots that can be used to examine the goodness of the model fit:

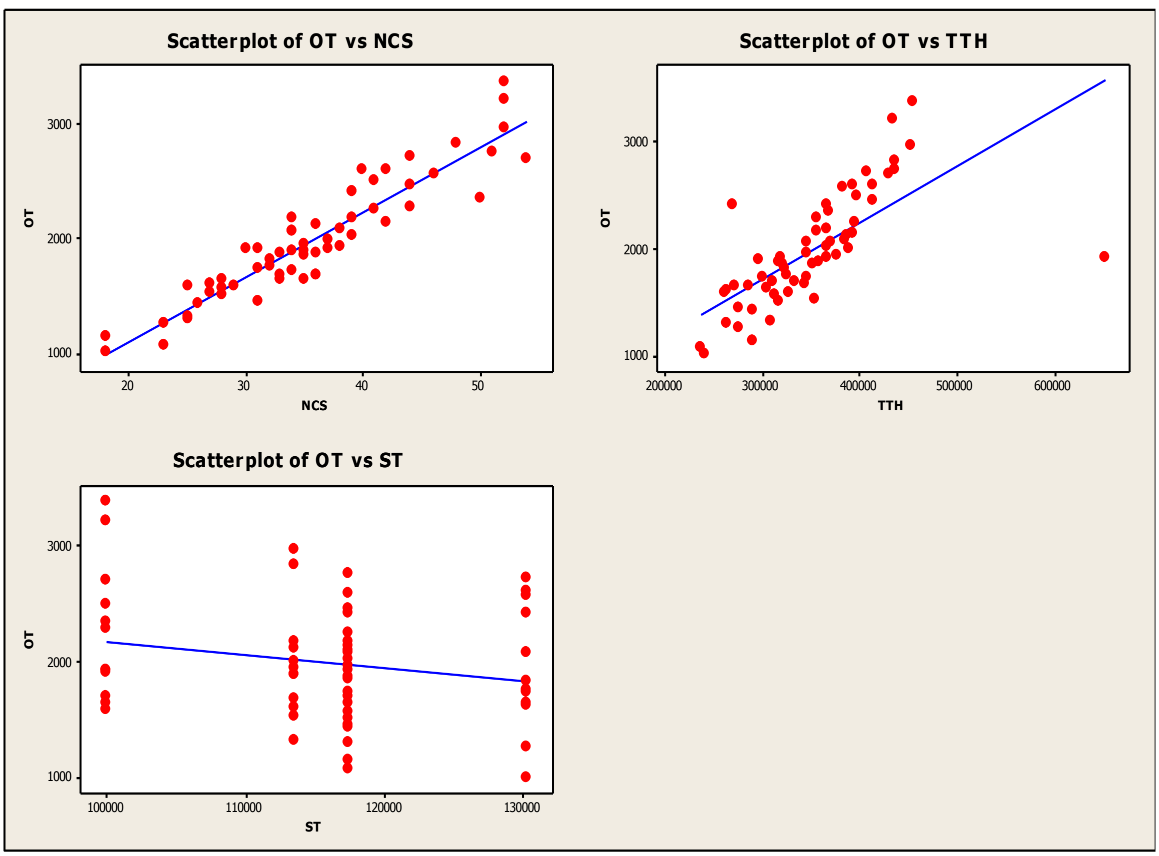


Figure 5.13- Scatter Plot of OT_{dr} vs. NCS, TTH and ST

Figure 5.13 examines the relationship between OT_{dr} and each predictor. It was found that NCS and TTH predictors positively affect OT_{dr}, with the exception of ST which has a negative effect. The figure shows that:

1. As usual, there is a strong relationship between OT_{dr} and NCS. An increase in the number of ships calling at Damietta port will result in increased total operation time.
2. For the ST predictor, the problem is that the port has expanded the storage areas for general cargo. This expansion may increase or lower the volumes handled at the terminal. It does not fit a straight line.
3. For the TTH predictor, handling dry bulk cargo depends on the handling rates per hour set by the port authority (LDR predictor), which is considered high in Damietta port.

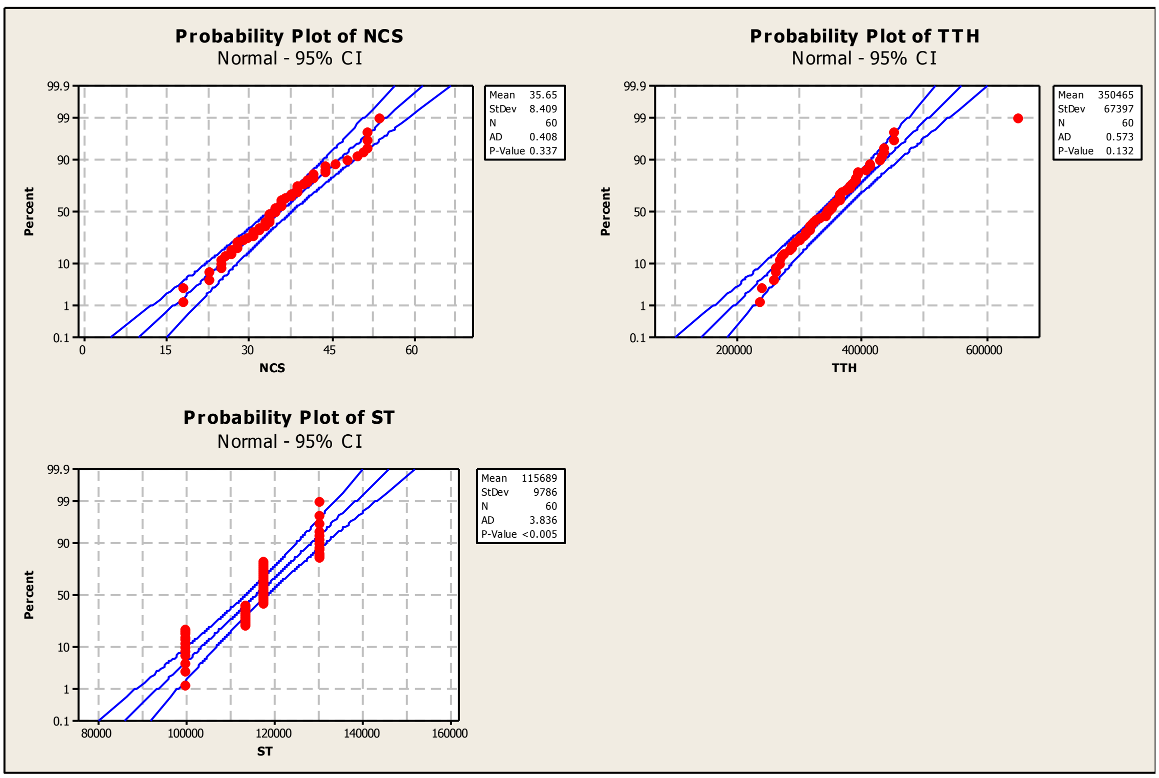


Figure 5.14- Probability Plot of NCS, TTh and ST

Figure 5.14 shows that the points for NCS and TTH form a nearly linear pattern, which indicates that the normal distribution is a good model for this data set. In the probability plot for ST, it is observed that there is a general linear trend with ST going up with OT_{dr}. This could be the result of an unusual activity level.

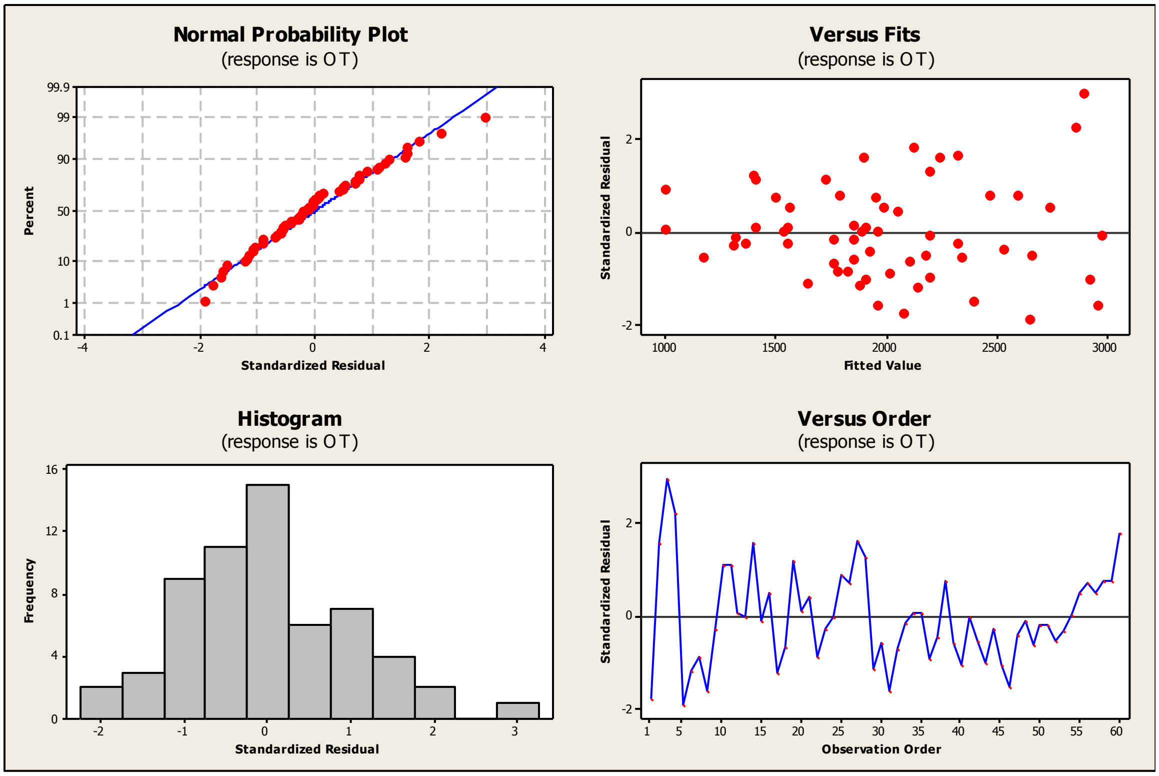


Figure 5.15- Residual Plots for OT_{dr}

Figure 5.15 displays the residual plots for the model that includes only those predictors that were found important.

1. **Normal probability plot-** There does not seem to be any great deviation in the normal probability plot of the residuals.
2. **Residuals versus fits-** It indicates that there is not a predominance of either positive or negative residuals, as residuals are randomly distributed about zero and less concentrated.
3. **Histogram** - The histogram shows the distribution of all residuals for all observations. It shows that there is a small outlier.
4. **Residuals versus order-** The versus order shows that there is no correlation between random errors, which means that they are independent of each other. It means the regression follows that assumption of OLS estimation.

5. **Stepwise regressions –** the advantage of the **Stepwise** method is that it results in the best fitting model. Table 5.7 shows that the best fitting model was selected in the linear multiple regression model. The predictors NCS, TTH and ST contributed significantly in the prediction of OT_{dr} R-sq equals about 89% and S equals 170.

Table 5.7- Stepwise Regression: OT_{dr} versus NCS, TTH, BO, LDR, ST

Response is OT on 5 predictors, with N = 60

Step	1	2	3
Constant	-34.38	-274.44	-1110.30
NCS	56.8	49.9	51.2
T-Value	19.13	14.09	14.97
P-Value	0.000	0.000	0.000
TTH		0.00140	0.00159
T-Value		3.16	3.72
P-Value		0.003	0.000
ST			0.0062
T-Value			2.56
P-Value			0.013
S	192	179	170
R-Sq	86.32	88.36	89.58
R-Sq(adj)	86.09	87.95	89.02
Mallows Cp	15.3	6.7	2.3
PRESS	2325929	2421242	2153370
R-Sq(pred)	85.11	84.50	86.21

6. **Best Subsets Regression**- it shows that the best model with larger R-sq is picked out as in Table 5.8. This model includes NCS, TTH and ST predictors. It proves that the best model is:

$$\mathbf{OT_{dr} = -1110 + 51.2\ NCS + 0.00159\ TTH + 0.00622\ ST} \quad (9)$$

Table 5.8- Best Subsets Regression: OT_{dr} versus NCS, TTH, BO, LDR, ST

Response is OT

Vars	R-Sq	R-Sq(adj)	Mallows Cp	S	NCS	TTH	BO	LDR	ST
1	86.3	86.1	15.3	191.89	X				
1	47.8	47.0	215.9	374.72		X			
2	88.4	88.0	6.7	178.55	X	X			
2	87.0	86.5	13.7	188.69	X				X
3	89.6	89.0	2.3	170.47	X	X			X
3	88.5	87.9	7.8	178.81	X	X	X		
4	89.6	88.9	4.1	171.67	X	X		X	X
4	89.6	88.8	4.2	171.88	X	X	X		X
5	89.6	88.7	6.0	173.07	X	X	X	X	X

5.4.3 Liquid Bulk Regression Analysis

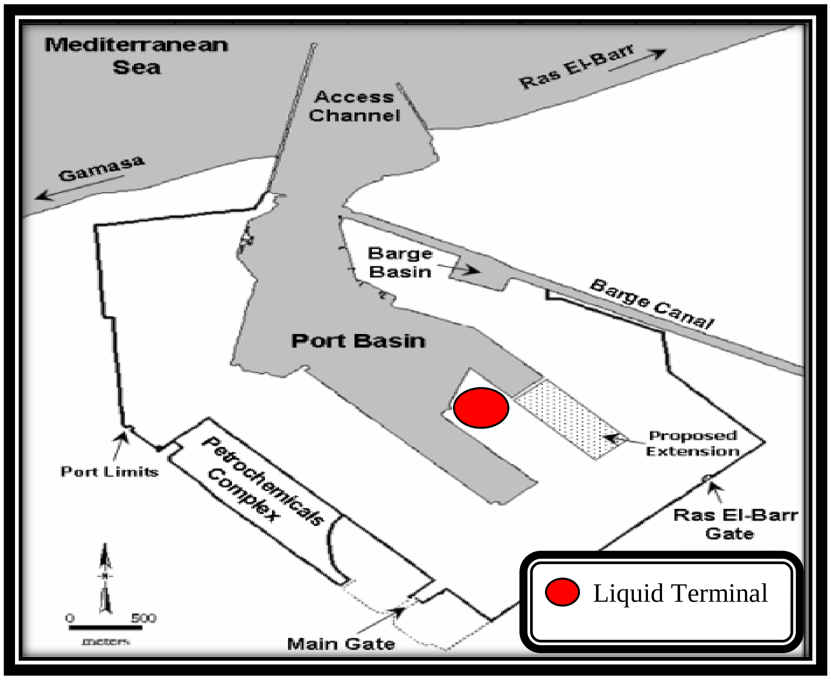


Figure 5.16- Liquid Bulk Terminal

The liquid bulk terminal has one multipurpose berth (berth no. 12) with a total length of 225 meters long and depth of 12 meters. Figure 5.16 shows that the terminal is served with 500,000 m^2 storage area, which has 63 tanks that can store up to 60,000 tonnes. The annual handling rate at the terminal is 563,000 tonnes.

Following the same steps as discussed earlier, many simple and multiple regressions have been performed to find out the best fitting model. OT_{liq} is the response variable in all the models performed. Non-significant predictors have been removed from the model without significantly reducing the model's predictive capability. Equation (10) shows one of the regression models that has not been selected, (See Appendix F) namely OT_{liq} versus TTH, LDR.

$$\mathbf{OT_{liq} = -384 + 0.00426\ TTH - 0.00300\ LDR} \qquad (10)$$

Predictor	Coef	SE Coef	T	P
Constant	-384.1	503.9	-0.76	0.449
TTH	0.004259	0.001623	2.62	0.011
LDR	-0.003000	0.004555	-0.66	0.513

S = 329.150   R-Sq = 11.3%   R-Sq(adj) = 8.2%

This example shows a very weak relationship between OT_{liq} and TTH and LDR. R-sq is weak and the p-value indicates that the relationship between OT_{liq} and predictors is not significant. The standard error of the estimate, S, equals 329.150, which is considered high in terms of the estimated standard deviation about the regression line.

Many simple and multiple regression models have been performed to find the best fitting model. In the case of liquid bulk, the regression models are different as there is more than one best-fitting model. In equation (11), all the predictors have a significant relationship with $OT_{liq.}$ F values, in both models, prove that the models as a whole are statistically significant. The F value is about 378 in the equation (11), and 414 in the equation (12).

$$\mathbf{OT_{liq} = -137 + 42.0\ NCS + 2.01\ BO + 0.00299\ LDR} \qquad (11)$$

Predictor	Coef	SE Coef	T	P
Constant	-136.86	51.75	-2.64	0.011
NCS	42.011	4.267	9.85	0.000
BO	2.0067	0.5807	3.46	0.001
LDR	0.0029852	0.0009947	3.00	0.004

S = 76.4436   R-Sq = 95.3%   R-Sq(adj) = 95.0%

$$\mathbf{OT_{liq} = -441 + 41.2\ NCS + 0.00131\ TTH + 1.90\ BO} \qquad (12)$$

Predictor	Coef	SE Coef	T	P
Constant	-440.8	115.1	-3.83	0.000
NCS	41.207	4.079	10.10	0.000
TTH	0.0013091	0.0003399	3.85	0.000
BO	1.9013	0.5394	3.53	0.001

S = 73.2313   R-Sq = 95.7%   R-Sq(adj) = 95.5%

The outputs found that the best three-predictor model for OT_{liq} is NCS, TTH and ST. Equation (13) gives the best regression model for liquid bulk cargo.

$$\mathbf{OT_{liq} = -6 + 43.8\ NCS + 0.00215\ TTH - 0.0137\ ST} \quad (13)$$

```
Predictor        Coef    SE Coef      T      P
Constant         -6.4      126.5  -0.05  0.960
NCS            43.837      2.775  15.80  0.000
TTH         0.0021531  0.0003957   5.44  0.000
ST          -0.013722   0.002998  -4.58  0.000


S = 69.0556   R-Sq = 96.2%   R-Sq(adj) = 96.0%
```

The interpretation of the regression equation is as follows:

1. The slope (b1 = 43.8) is the change in OT_{liq} when NCS increases by 1. That is, when the NCS increases by one unit, the OT_{liq} increases by 43.8 units.
2. The slope (b2 = 0.00215) is the change in OT_{liq} when TTH increases by 1. That is, when the TTH increases by one unit, the OT_{liq} increases by 0.00215 units.
3. The slope (b3 = 0.0137) is the change in OT_{liq} when ST increases by 1. That is, when ST increases by one unit, the OT_{liq} increases by 0.0137 units.
4. The constant (intercept) value (bo = - 6) is the predicted value of OT_{liq} when each predictor (NCS, TTH and ST) is zero. That is, when the predictors are zero the OT_{liq} is - 6.

It was difficult to select the best fitting model as there were many goodness-of-fit models. The best model above has excluded the 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. Thus, removing it from the model eliminated the impact of multicollinearity. The following correlation matrix indicates that there is a significant relationship between OT_{liq} and other predictors. In the correlation matrix, the BO predictor has a significant relationship with NCS as it accounted for 91% and with ST, by - 84%. Also, a VIF test shows that BO's VIF equals 11.7 indicating high multicollieanarity.

Table 5.9- Correlations: OT_{liq}, NCS, TTH, BO, LDR, ST

	OT	NCS	TTH	BO	LDR
NCS	0.969				
	0.000				
TTH	0.326	0.249			
	0.011	0.055			
BO	0.915	0.912	0.139		
	0.000	0.000	0.290		
LDR	0.077	0.020	0.459	-0.116	
	0.561	0.881	0.000	0.379	
ST	-0.731	-0.724	0.229	-0.840	0.229
	0.000	0.000	0.078	0.000	0.079

Cell Contents: Pearson correlation
P-Value

The analysis of Table 5.9 is as follows:

1. It shows that NCS, TTH, BO and LDR have positive effects on OT_{liq}, except ST for which the correlation coefficient is negative.
2. This means that when NCS, TTH, BO and LDR increase, OT_{liq} also tends to increase.
3. The correlation between OT_{liq} and NCS has the strongest relationship that accounted for about 96%, followed by BO at 91%.
4. There is a moderate correlation between LDR and TTH that accounted for about 45%.

5. There is a negative relation between ST at Damietta port and BO that accounts for about - 84%.
6. The weakest relationship exists between the NCS and LDR predictors.
7. The main argument in the correlation matrix is that the relationship between NCS and BO comes to 91%. The decision was made to exclude this predictor for two reasons. First, exclusion aimed to reduce multicollinearity as there is a perfect relationship with NCS. Secondly, this is because most liquid cargo necessitates safety measurements prior to, during and after loading. Ships are subject to safety inspection by the loading station management, and this takes a long time. Also, some measurements should be performed before starting the loading operation; such as checking the level of liquid in tanks, 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 is time consuming and in turn affects OT_{liq}. 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.
8. The LDR predictor is not statistically significant, as p-value = 0.102. Also, this predictor has no real influence on OT_{liq}. 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. This means that LDR takes longer. The decision was therefore made to exclude LDR.
9. The following figures display the residual plots that can be used to examine the goodness of fit of the model:

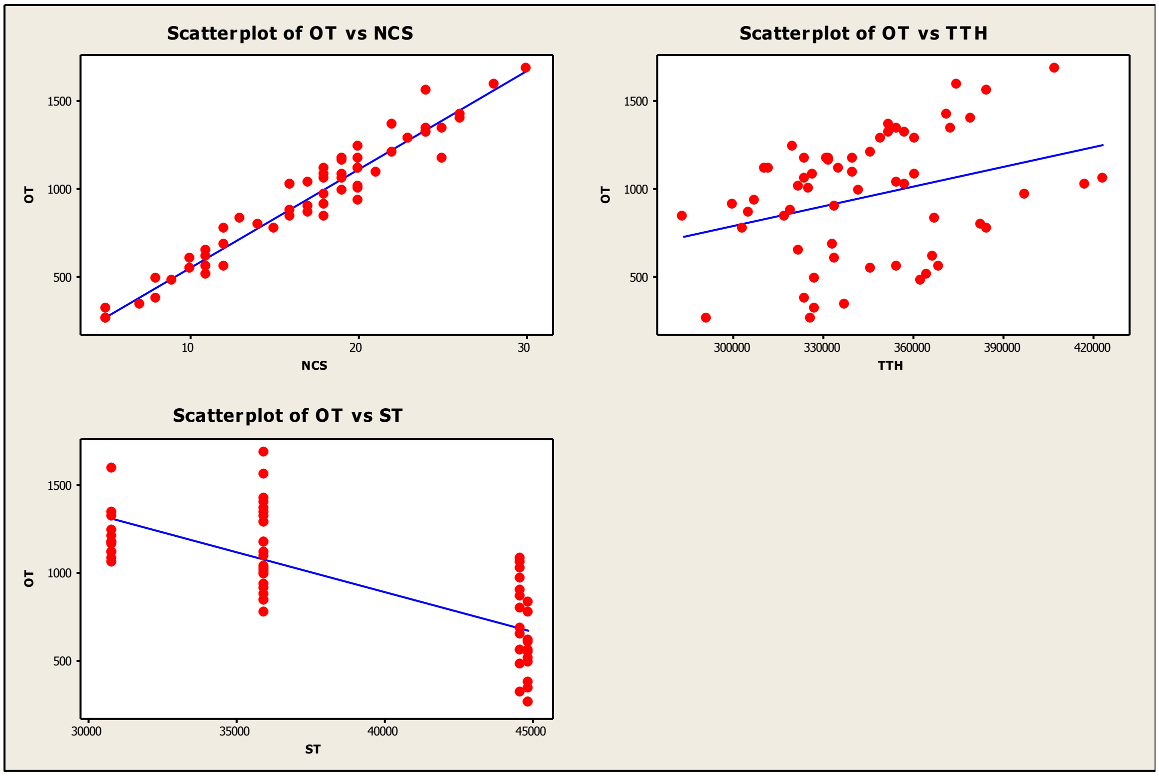


Figure 5.17- Scatter Plot of OT_{liq} vs. NCS, TTH and ST

Figure 5.17 examines the relationship between OT_{liq} and each predictor. The figure shows that:

1. There is a strong positive relationship between OT_{liq} and NCS, Based on the values of the correlation coefficient, it is evident that this relationship is relatively linear.
2. For the TTH predictor, the distance between each point and the line, in both figures, is statistically a measure of error. That is, each of these distances represents places where the line does not fit the data exactly. But, it is agreed that the amount of error around the line is small. Hence, variability can be accepted, particularly, when the port managers recommend handling high volumes of liquids for economies of scale purposes, because ships stay a long time with limited operations. For this reason, and because berth no 12 is the only berth that is dedicated for liquid bulk, tanker ships are sometimes loaded and discharged off-shore. Hence, data for the TTH predictor varies little with OT_{liq}.

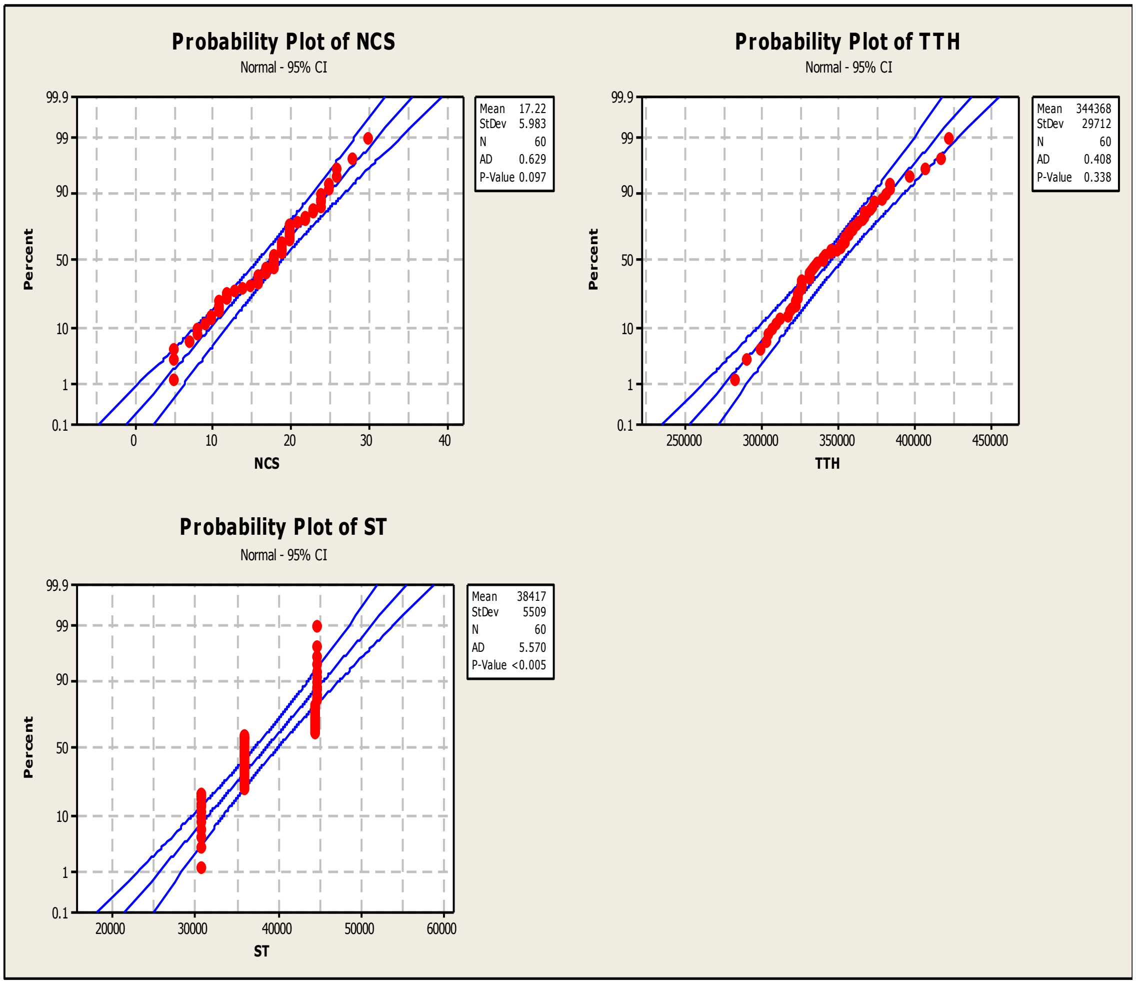


Figure 5.18- Probability Plot of NCS, TTH and ST

Figure 5.18 shows that the points for NCS and TTH form a linear pattern, which indicates that the normal distribution is a good model for this data set. For the probability plot for ST, almost all of its points are not near the straight line. This is because the rate of loading and discharging varies as discussed earlier.

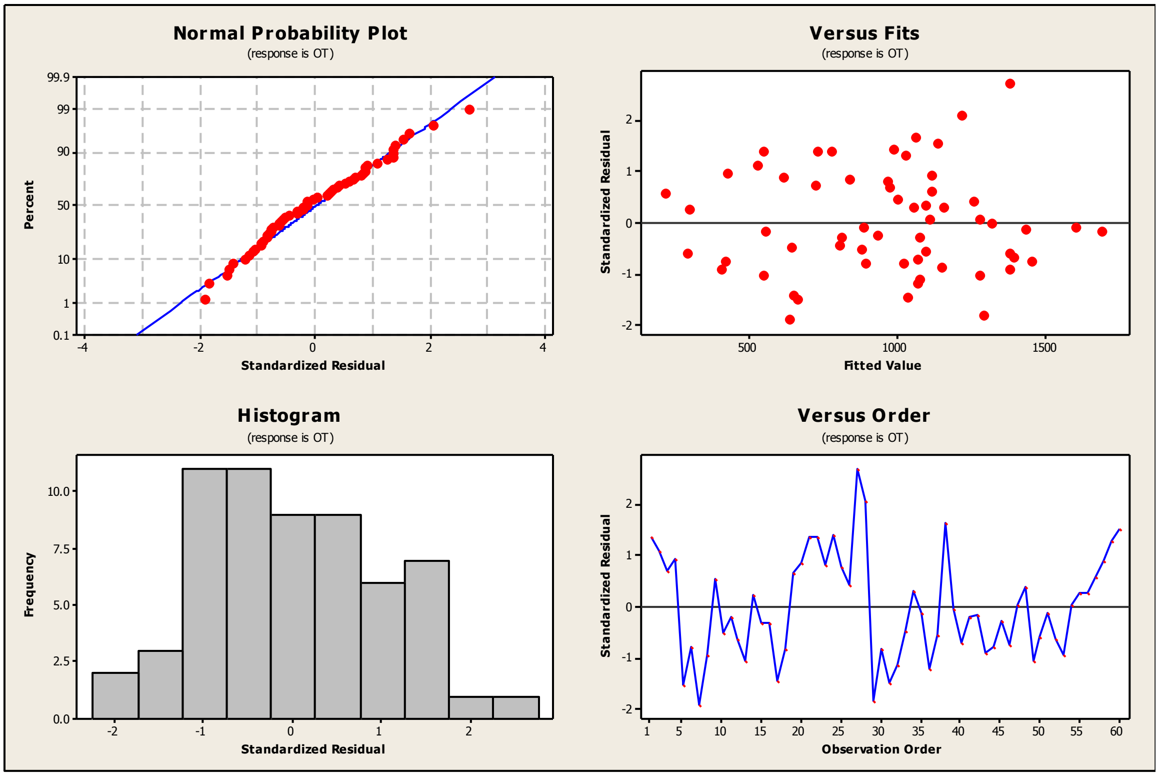


Figure 5.19- Residual Plots for OT_{liq}

Figure 5.19 displays the residual plots for the model that includes only those predictors that were found important.

1. **Normal probability plot-** There does not seem to be any great deviation in the normal probability plot of the residuals.
2. **Residuals versus fits**- It indicates that there is no predominance of either positive or negative residuals, as residuals are randomly distributed about zero and less concentrated.
3. **Histogram** - The histogram shows the distribution of all residuals for all observations. It shows that there is a small outlier observation.
4. **Residuals versus order-** The versus order shows that there is no correlation between random errors, which means that they are independent of each other.
5. **Stepwise regressions -** The following stepwise outcome in Table 5.10 verifies that the best fitting model was selected in the linear multiple regression model. The predictors NCS, TTH and ST contributed significantly in the prediction of OT_{liq}.

Table 5.10- Stepwise Regression: OT_{liq} versus NCS, TTH, BO, LDR, ST

Response is OT on 5 predictors, with N = 60

Step	1	2	3
Constant	4.399	-332.167	-6.423
NCS	55.7	54.4	43.8
T-Value	30.06	30.16	15.80
P-Value	0.000	0.000	0.000
TTH		0.00104	0.00215
T-Value		2.87	5.44
P-Value		0.006	0.000
ST			-0.0137
T-Value			-4.58
P-Value			0.000
S	85.1	80.2	69.1
R-Sq	93.97	94.73	96.16
R-Sq(adj)	93.86	94.54	95.96
Mallows Cp	34.0	24.7	5.2
PRESS	444442	403198	305020
R-Sq(pred)	93.62	94.21	95.62

6. **Best Subsets Regression**- Table 5.11 shows that the best models with larger R-sq are selected as in the following output. This model includes NCS, TTH and ST predictors. It proves that the best model is:

$$\mathbf{OT_{liq} = -6 + 43.8\ NCS + 0.00215\ TTH - 0.0137\ ST} \qquad (14)$$

Table 5.11- Best Subsets Regression: OT_{liq} versus NCS, TTH, BO, LDR, ST

Response is OT

Vars	R-Sq	R-Sq(adj)	Mallows Cp	S	NCS	TTH	BO	LDR	ST
1	94.0	93.9	34.0	85.094	X				
1	83.8	83.5	185.9	139.50			X		
2	94.7	94.5	24.7	80.236	X	X			
2	94.5	94.4	27.4	81.636	X		X		
3	96.2	96.0	5.2	69.056	X	X			X
3	95.7	95.5	12.4	73.231	X	X	X		
4	96.3	96.0	5.9	68.860	X	X		X	X
4	96.2	96.0	6.2	69.030	X	X	X		X
5	96.4	96.0	6.0	68.301	X	X	X	X	X

5.4.4. Container Cargo Regression Analysis

Container ships are generally classified into generations. Each generation carries a certain amount of containers. The terminal receives all container ships up to third generation. Figure 5.20 shows the container terminal, which provides a specified level of services such as proper cargo handling equipment in ship-side and land-side and berth lengths. The terminal has four berths (no. 1, 2, 3 and 4) with a total length of 1050 metres and depth of 14.5 metres. The container yard is 1,000,000 m^2 and can store 1.2 million TEUs.

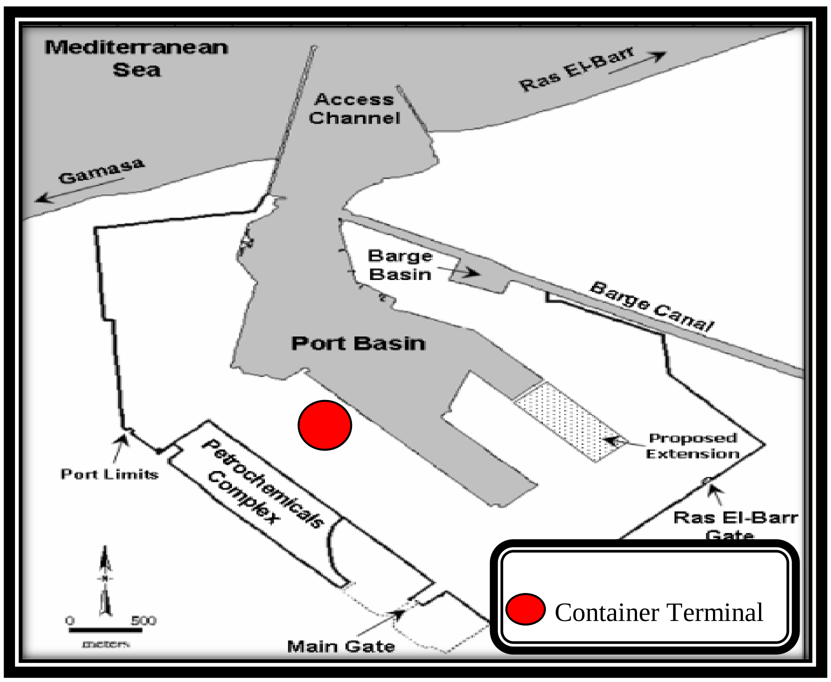


Figure 5.20- Container Terminal

Following the same steps as in previous types of cargoes, many simple and multiple regressions have been performed to find out the best fitting model. OT_{con} is the response variables in all the models performed. The best fitting model has been selected where the best proportion of the variance in the values of OT_{con} is explained by all predictors. Non-relevant models (See Appendix G) have been excluded such as in the equation (15).

$$\mathbf{OT_{con} = - 1110 + 38.4\ BO - 0.00056\ ST} \qquad (15)$$

Predictor	Coef	SE Coef	T	P
Constant	-1109.7	697.5	-1.59	0.117
BO	38.355	8.805	4.36	0.000
ST	-0.000555	0.002040	-0.27	0.786

S = 246.060   R-Sq = 25.1%   R-Sq(adj) = 22.5%

This example shows a very weak relationship between OT_{con} and BO and ST. R-sq is weak and the p-value indicates that the relationship between OT_{con} and the predictors is not significant. The standard error of the estimate, S, equals 246.060, which is considered high in terms of the estimated standard deviation about the regression line.

Many simple and multiple regression models have been regressed to find out the best fitting model. In case of the container cargo, the regression models are different. There are many regressions where the predictors are significant but the R-sq is quite small. Thus, those models have not been selected as R-sq describes the amount of variation in the observed response values. Equation (16) shows one of those models.

$$\mathbf{OT = - 889 + 0.000599\ TTH + 27.7\ BO} \qquad \mathbf{(16)}$$

Predictor	Coef	SE Coef	T	P
Constant	-889.3	644.2	-1.38	0.173
TTH	0.0005990	0.0001837	3.26	0.002
BO	27.747	8.583	3.23	0.002

S = 226.041   R-Sq = 36.8%   R-Sq(adj) = 34.6%

The outputs found that the best four-predictor model estimating OT_{con} is NCS, BO, LDR and ST. Equation (17) displays the best regression model for container cargo.

$$\mathbf{OT_{con} = -815 + 14.9\ NCS + 11.1\ BO + 0.0540\ LDR - 0.00285\ ST} \tag{17}$$

```
Predictor        Coef   SE Coef      T      P
Constant       -814.8     373.7  -2.18  0.034
NCS            14.899     1.660   8.97  0.000
BO             11.102     5.267   2.11  0.040
LDR           0.05396   0.04946   1.09  0.280
ST          -0.002849  0.001109  -2.57  0.013


S = 131.554   R-Sq = 79.4%   R-Sq(adj) = 77.9%
```

The interpretation of the regression equation follows:

1. The slope (b1 = 14.9) is the change in OT_{con} when NCS increases by 1. That is, when the NCS increases by one unit, the OT_{con} increases by 14.9 units.
2. The slope (b2 = 11.1) is the change in OT_{con} when BO increases by 1. That is, when the BO increases by one unit, the OT_{con} increases by 11.1 units.
3. The slope (b3 = 0.0540) is the change in OT_{con} when LDR increases by 1. That is, when LDR increases by one unit, the OT_{con} increases by 0.0540 units.
4. The slope (b4 = 0.00285) is the change in OT_{con} when ST increases by 1. That is, when ST increases by one unit, the OT_{con} increases by 0.00285 units.
5. The constant (intercept) value (bo = - 815) is the predicted value of OT_{con} when each predictor (NCS, BO, LDR and ST) is zero. That is, when the predictors are zero the OT_{con} is - 815.

Two best fitting models emerged as follows:

1. One model has included all predictors, except TTH where R-sq = 78%.
2. The second model included all predictors except LDR where R-sq = 77.9%.

It is obvious that the selected model has excluded TTH (78%). Firstly, there is statistically no real difference between the two R-sq's. Secondly, the relationship between OT_{con} and TTH is low. The reason is the transit shipment. A percentage of containers are handled in order to be re-exported. 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 the number of 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, the VIF test shows that including the TTH variable will lead to poor estimation (Montgomery and Peck, 1982). VIF equals 5 with milled multicollieanarity in the case of including TTH.

The data analysis shows that the number of container ships calling at Damietta port increased in the year 2008 (1220 container ships) compared with the year 2007 (988 container ships) and the year 2006 (875 container ships). This explains why such an increase in NCS would increase OT_{con}.

The BO predictor is significant as there were some shipping lines such as P&O shipping line and Maersk shipping line that directed their ships to East-Port Said port. Also, the CMA shipping line moved some of its ships to Beirut in Lebanon. This is because the depth in container berths at Damietta port is insufficient for their container ships. However, there are new Chinese shipping lines calling regularly at the port. This explains why BO influences OT_{con} over the time.

For the ST predictor, the port has started to build a new container terminal with international standards. Kuwait and Gulf Link Holding Company (KGL) invested USD 800 million in this project to handle 4 million TEUs in Damietta port. The project is expected to be completed in 2012.

Table 5.12 indicates that there is a significant relationship between OT_{con} and other predictors. In the correlation matrix, the NCS predictor has the most significant relationship with OT_{con} as it accounted for 86%.

Table 5.12- Correlations: OT_{con}, NCS, TTH, BO, LDR, ST

	OT	NCS	TTH	BO	LDR
NCS	0.864				
	0.000				
TTH	0.502	0.615			
	0.000	0.000			
BO	0.500	0.443	0.366		
	0.000	0.000	0.004		
LDR	0.646	0.669	0.633	0.404	
	0.000	0.000	0.000	0.001	
ST	0.048	0.226	0.664	0.157	0.134
	0.717	0.083	0.000	0.230	0.309

The analysis of the above correlation is:

1. It shows that all predictors have positive effects on OT_{con}.
2. This means that when predictors increase, OT_{con} also tends to increase.
3. There is a moderate correlation between TTH and BO and OT_{con}.
4. There is no negative relation between any predictors and each other.
5. It is observed that there are relationships between predictors, but multicollinearity is low; such as the correlation between NCS and BO is about 44%.
6. The following figures display the residual plots that can be used to examine the goodness of fit:

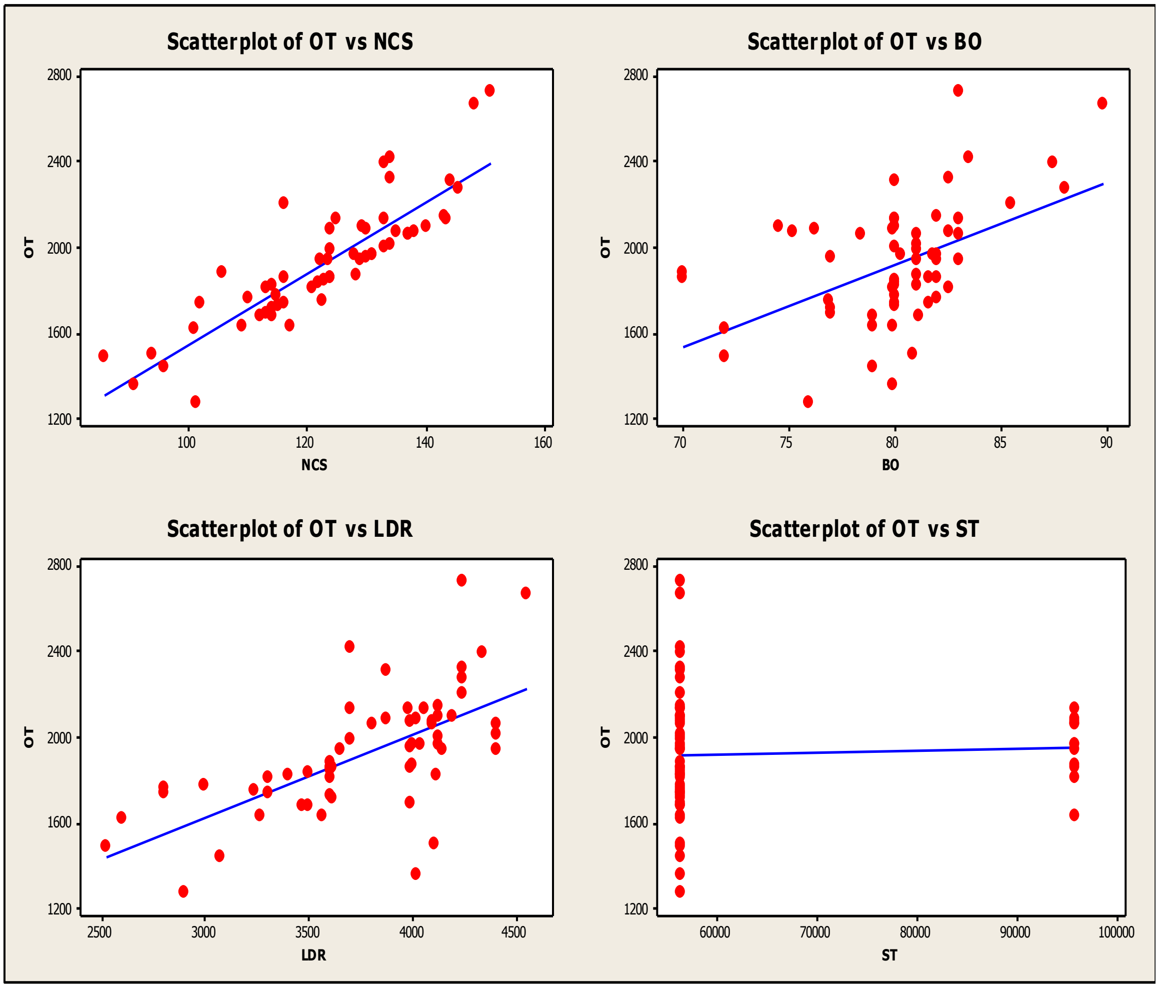


Figure 5.21- Scatter Plot of OT_{con} vs. NCS, BO, LDR and ST

Figure 5.21 examines the relationship between OT_{con} and each predictor. The figure shows that:

1. There is a strong positive relationship between OT_{con} and NCS. Based on the values of the correlation coefficient, it is evident that this relationship is relatively linear.
2. For the BO and LDR predictors, the distance between each point and the line, in both figures, is statistically a measure of error. That is, each of these distances represents places where the line does not fit the data exactly. But, Figure 5.22 shows that the amount of error around the line is small. Hence, variability can be accepted.

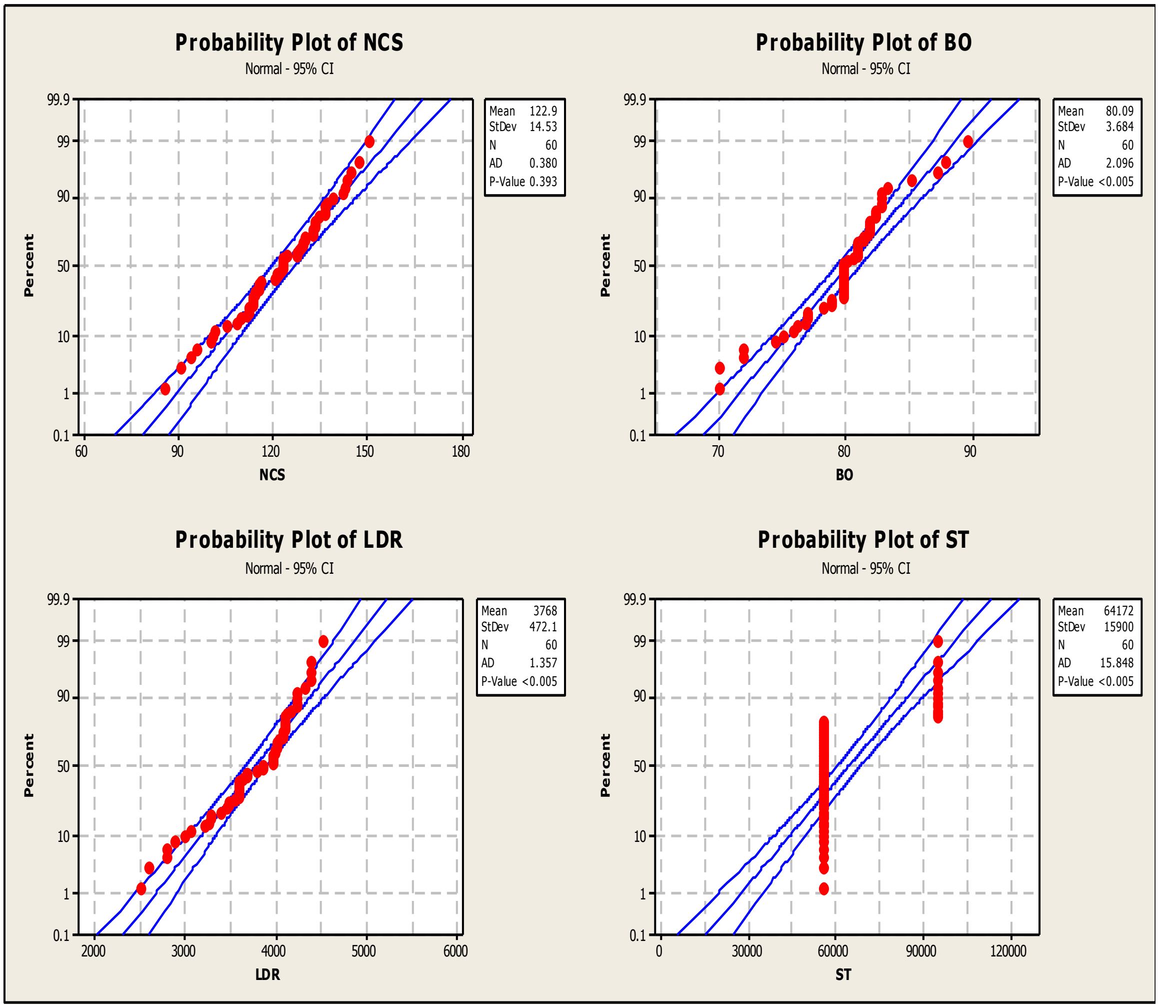


Figure 5.22- Probability Plot of NCS, BO, LDR and ST

Figure 5.22 shows that the points for NCS, BO and LDR form a linear pattern, which indicates a normal distribution for this data set. For the probability plot for ST, almost all of its points are not near the straight line. This is because the rate of loading and discharging varies as discussed earlier, and is not related to storage capacity. Also, DPA has started to expand its current terminal through increasing the storage areas.

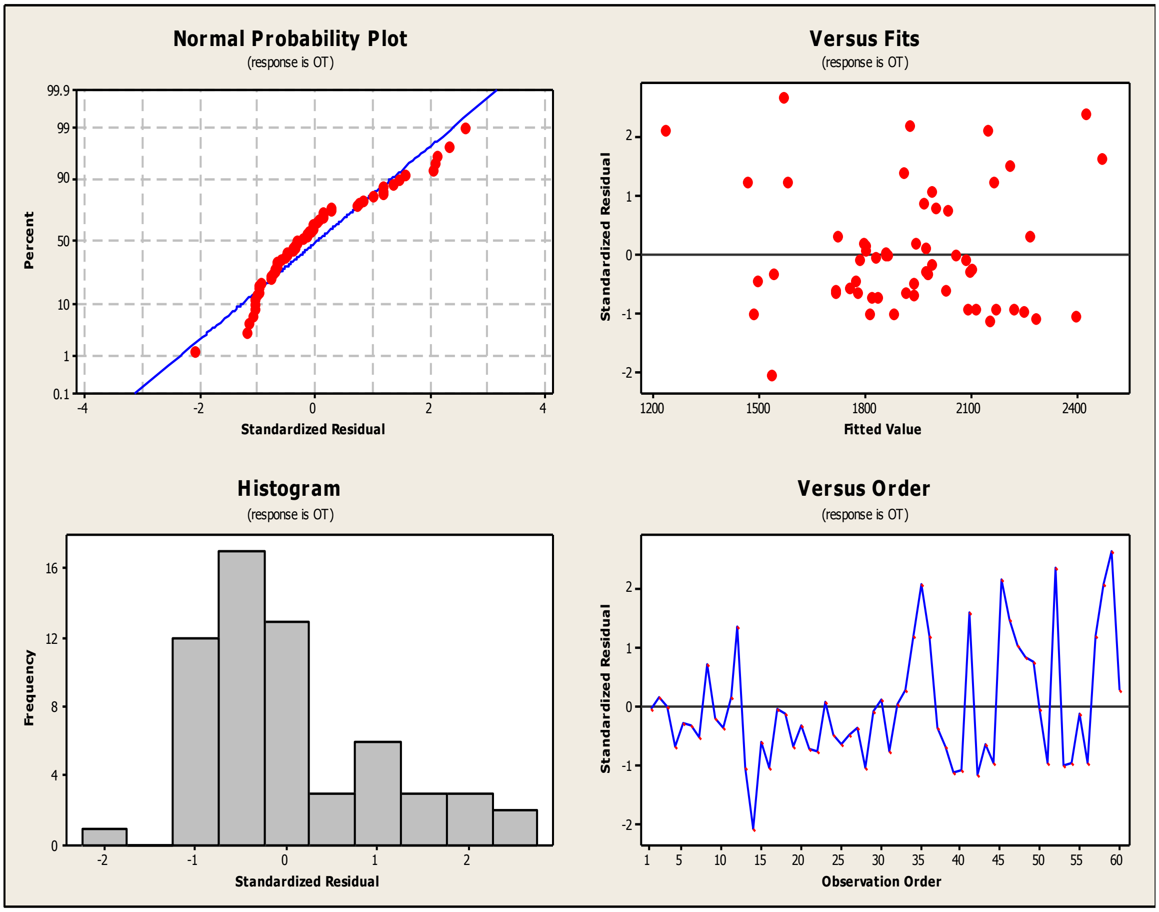


Figure 5.23- Residual Plots for OT_{con}

Figure 5.23 displays the residual plots for the model that includes only those predictors that were found important.

1. **Normal probability plot-** There does not seem to be any great deviation in the normal probability plot of the residuals.
2. **Residuals versus fits**- It indicates that there is no predominance of either positive or negative residuals, as residuals are randomly distributed about zero and less concentrated.
3. **Histogram-** The histogram shows the distribution of all residuals for all observations. It shows that there is a small outlier of observation.
4. **Residuals versus order-** The versus order shows that there is no correlation between random errors, which means that they are independent of each other.

5. **Stepwise regressions –** Table 5.13 shows that the highest R-sq is in step 4, where NCS, BO, LDR and ST predictors contributed to the prediction of $\mathbf{OT_{con}}$.

Table 5.13- Stepwise Regression: $\mathbf{OT_{con}}$ versus NCS, TTH, BO, LDR, ST

Response is OT on 5 predictors, with N = 60

Step	1	2	3	4
Constant	484.5	-196.9	-103.0	-814.8
LDR	0.383	0.074	0.071	0.054
T-Value	6.45	1.41	1.41	1.09
P-Value	0.000	0.163	0.163	0.280
NCS		15.0	15.7	14.9
T-Value		8.85	9.47	8.97
P-Value		0.000	0.000	0.000
ST			-0.0027	-0.0028
T-Value			-2.36	-2.57
P-Value			0.022	0.013
BO				11.1
T-Value				2.11
P-Value				0.040
S	215	141	136	132
R-Sq	41.79	75.47	77.69	79.35
R-Sq(adj)	40.79	74.61	76.49	77.85
Mallows Cp	97.9	10.8	7.0	4.6
PRESS	2873890	1285530	1192631	1185890
R-Sq(pred)	37.67	72.12	74.13	74.28

6. **Best Subsets Regression**- Table 5.14 shows that the best models with larger R-sq are picked as in the following output. There are two best models. The following best subsets regression outputs display the higher R-sq and lower S. It is concluded that the best model includes NCS, BO, LDR and ST predictors as follows:

$$\mathbf{OT_{con} = - 815 + 14.9\ NCS + 11.1\ BO + 0.0540\ LDR - 0.00285\ ST} \qquad (18)$$

Table 5.14- Best Subsets Regression: OT_{con} versus NCS, TTH, BO, LDR, ST

```
Response is OT

N T   L
Mallows          C T B D S
Vars  R-Sq  R-Sq(adj)       Cp       S  S H O R T
1  74.6       74.2     11.1  142.05  X
1  41.8       40.8     97.9  215.10        X
2  76.9       76.1      7.1  136.72  X       X
2  76.4       75.5      8.5  138.30  X   X
3  78.9       77.8      3.8  131.78  X   X   X
3  77.7       76.5      6.9  135.41  X X     X
4  79.5       78.0      4.3  131.19  X X X   X
4  79.4       77.9      4.6  131.55  X   X X X
5  79.6       77.7      6.0  132.07  X X X X X
```

5.5 Interpretation of all Regression Analyses

Multiple regression analyses have been performed to explain the variability of OT. Five predictors were used: NCS, TTH, BO, LDR and ST, where OT was the response variable. It is obvious that the relationship between the response and the predictors is linear. The residuals are distributed normally, where histograms for the residuals and normal probability plots have been applied to inspect the distribution of the residual values. Multicollinearity has been considered by removing some of those predictors that have a perfect relationship with the response.

Multiple regression analyses, stepwise regressions and best subsets regressions have been performed to determine the significance of the key predictors in the prediction of OT. General conclusions can be observed after performing the regression analyses as follows:

1. Not all predictors are significant in all types of cargo.
2. The NCS predictor has a significant relationship with OT in the four best-fitting models. This is because the port is competing with other Egyptian ports and Mediterranean ports which attract more shipping lines, shippers and stevedoring companies. The port competition takes place in terms of reducing ship-turnaround time, pricing, customs and quality services.
3. The ST predictor is significant in all types of cargo with OT. Storage plays an important role for all types of cargo. In liquid bulk, new generations of liquid bulk ships have higher cargo-carrying capability, which requires continuous improvements in berth design and shore storage tank capacity. In dry bulk, handling huge volumes of bulk cargo requires a sufficient number of storage areas with proper capacity for allowing physical movement. A proper storage plan is required to handle an increase in the number of containers handled at the port, such as determining the number of stacks and handling facilities for both empty and loaded container.

4. Also, general cargo requires different storage areas as there are different types of cargoes carried by general cargo ships.
5. The same predictors have the same significance in dry bulk and liquid bulk. These predictors are: NCS, TTH and ST. This is due to the high volumes that both terminals handle at Damietta port.
6. The LDR predictor only has a significant relationship with OT in container cargo. This is because of reduced flow rates at the beginning and end of discharge for liquid and dry bulk. There is no fixed rate of handling in both types of cargo. In general cargo, the handling rate does not reflect the volumes of cargo handled at the port, particularly if it is light cargo.
7. The BO predictor is only significant in general cargo and container cargo. Dry bulk ships and liquid bulk ships stay longer due to the required measurement and inspections.
8. The TTH predictor is not significant with OT in container cargo. This is because there is no need for intermediate handling at the container terminal, where containers are being discharged directly from a ship to trucks that are waiting alongside the berth. Accordingly, CT is zero at the container terminal. Thus, the maritime container shipments are quicker and in turn, it increases the service frequency. This has encouraged DPA to invest in expanding the terminal by establishing a new container terminal.

5.6 DAPEMS Structure

Egyptian ports are receiving an increasing number of calling ships and they handle huge volumes of different types of cargo. The number of calling ships has increased by 3.4% in the year 2008 in comparison with 2007. In 2009, there were 20,278 ships calling at Egyptian ports, carrying 312.1 million tonnes. However, this increase in NCS has affected ship turn-around time, and consequently, it has affected how long a ship stays at ports. The length of a ship's stay has increased to 3 days per ship in 2009, compared to 2.7 days in 2008 and 3.5 days in 2007 (MTS, 2010).

In addition, the total tonnes handled at Egyptian ports have sharply increased by 6% between 2008 and 2009, compared to a 3.5% increase between 2007 and 2008. In 2009, the breakdown of products handled in Egyptian ports was 25.3% dry bulk, 15.4% general cargo, 10.5% liquid bulk and about 48.1% container cargo (MTS, 2010).

In Damietta port, the maximum capacity of the port as designed is to handle 19.7 million tonnes. However, the Ministry of Transport reported that the actual capacity of the port was 29.3 million tonnes in the year 2009 (MTS, 2010). It indicates that there is over utilisation of the port facilities, workers and equipment. However, there is only a slight increase in the number of ships calling at Damietta port. In 2006, 3002 ships called at the port, 3245 ships in 2009 and 3259 ships in 2010 (MTS, 2010). Therefore, the port needs to have a reliable and an effective performance measurement system as this will help the port managers determine the effectiveness and efficiency of the port's facilities.

As discussed earlier in Chapter Four, there is no formal performance measurement system currently applied in the port. Hence, DAPEMS has been developed, based on time measures (see Table 5.15). The system measures the total time cargo stays in the port on a monthly basis. It is the sum of a range of different types of time. OT increases if there is more cargo to move, consequently, TS increases. OT, TS and CT can be used by the port managers as indicators to show if the port performance is improving or weakening.

Table 5.15- DAPEMS

Port	Damietta			
Type of cargo	**General Cargo**	**Dry Bulk**	**Liquid Bulk**	**Containers**
OT (hr)/month	OT_{gen} = - 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 (hr)/month	$TS_{gen} = OT_{gen} + 2SD_{gen} + BT_{gen} + UBt_{gen}$	$TS_{dr} = OT_{dr} + 2SD_{dr} + BT_{dr} + UBT_{dr}$	$TS_{liq} = OT_{liq} + 2SD_{liq} + BT_{liq} + UBT_{liq}$	$TS_{con} = OT_{con} + 2SD_{con} + BT_{con} + UBT_{con}$
CT(hr)/month	CT_{gen}	CT_{dr}	CT_{liq}	CT_{con}

Keys used in DAPEMS

1. TS = total time a ship stays in the port
2. CT = clearance time
3. NCS = number of calling ship
4. BO = berth occupancy
5. TTH = total tonnes handled in a given period
6. LDR = loading/discharging rate
7. OT = operations time
8. ST = storage
9. BT = berthing time
10. UBT = un-berthing time
11. SD = standing time

Table 5.15 shows the DAPEMS that has been developed using time measures. DAPEMS is mainly divided into four parts according to the type of cargo, as each type requires different performance calculations. Each type of cargo has specific characteristics in terms of the nature of the cargo handled, the available facilities at the terminal, the number of berths dedicated and special handling equipment required.

For each four types of cargo (general cargo, dry, liquid and containers), the performance calculation follows three steps:

1. At the first step, the system calculates OT using multiple regression analysis. Each type has a different regression model where most of the predictors do not have the same level of significance in all types of cargo.
2. In the second step, DAPEMS calculates TS. It cannot be calculated prior to OT as OT is part of TS. Other variables have been included in the calculation, including BT, UBT and SD.
3. The third step is the CT. This variable has not been calculated as the data is available at the port.
4. OT, TS and CT refer to the total time cargo stays in the port. Exporters, importers, shippers, carriers, port managers require ships to remain in port for the shortest possible time.

5.7 Chapter Summary

DPA has no formal measurement system as discussed in Chapter Four, as they rely on only two KPIs for measurement. Different determinants of port performance have been discussed. This helped determine those measures that should be considered in the required system. Cargo remaining in port is the response variable that influences the port performance. It is derived from the port strategy and meets the port managers' expectations. Those measures and variables used in developing the system have been grouped into five groups. It helped to select the key predictor variables that influence OT. TS has been calculated using different variables from those used in OT calculations. No calculation was needed for CT as data are available in the port's records.

OT has been calculated as a first step using regression analysis. Regression has been used as an analytical technique to develop multiple regression equations between OT and various predictors. Many regressions have been performed to find the best fitting model. Stepwise regression and best subsets regression have been applied to verify the best fitting models.

Different tests have been applied including: scatter plots, correlation matrix, probability plots, normality plots, histograms, residual errors versus orders and fits, stepwise regressions and best subset regressions. These tests ensured the linearity of the relationship, independence of the errors, and normality of the error distribution. It was obvious that not all predictors were significant for all types of cargo. Any increase or a decrease in OT, TS and CT will result in determining the port performance in terms of how long cargo stays in the port. Table 5.15 displays DAPEMS developed using time measures. In Chapter Six, DAPEMS will be developed by integrating other measures, such as revenue. It aims to develop a more effective and reliable measurement system to cope with the complexity of the port environment.

Chapter Six

Revenue and Flexibility Measures for DAPEMS System

6.1 Introduction

Maritime transport is the backbone of development for many countries (Cullinane et al., 2002). In Egypt, maritime transport handled 86% of total Egyptian freight in 2010 (JICA, 2011). This is because maritime transport is characterised by comfort movement i.e. the ability to handle heavy traffic of goods safely and at low cost. These characteristics have increased the sector's competitiveness compared to other modes of transport. Different mechanisms are used to measure the competitiveness in ports. Monitoring mechanisms aim to analyse the efficiency of port activities, and assist in the search for better tools to improve the service provided at these ports, as well as maximising revenues and minimising total costs.

Each port should implement appropriate management and performance metrics to meet its strategy. Most ports give more attention towards a strategy of revenue maximisation. However, in some ports, the main aim is to improve the service levels provided, without being interested in profit making (Talley, 2007).

Hence, a single performance measure cannot satisfactorily define port performance as it does not cover all aspects of the port operations. Neely and Adams (2002) argued that no individual performance measure can reflect business performance. Talley (2007) claimed that performance indicators should be consistent with a port's strategic objectives. He recommended using time and cost measures for assessing a port's performance.

There are a large number of different types of performance measurement approaches that can be used to characterise systems (Beamon, 1999). For example, customer responsiveness is used to identify performance measurement (Lee and Billington, 1993), and information flow has been used to characterise a measurement system (Nicoll, 1994 cited by Hervani et al. 2005).

Neely et al. (1995) presented a useful categorisation for systems analysis: time, cost, flexibility and quality. Neely's categorisation helps to improve the characteristics of a system, for example, time. Within this research study, a single type of measure has been evaluated, time, and within this category, many different specific measures of time have been developed such as OT. In this way, time measures help to provide criteria for the measurement of system design. The same idea can be applied using other measurement categories such as revenues.

In Chapter Five, time measures have been used to develop DAPEMS. Within time measures, the port performance is determined by how much time cargoes remain at ports. It helps Damietta port to control the port users' response time. It also aims to help the port managers by completing operations faster and to meet promised delivery dates reliably.

Hence, there is a need to integrate more measures in DAPEMS, namely revenue measures and flexibility measures. Revenue measures need to be considered in DAPEMS for the following reasons:

1. Any operation at ports generates costs which need to be passed on to the customers to create revenue for the port. This information can help in determining a port tariff system.
2. The performance measurement system should be inclusive (Beamon, 1999). Time refers to how long it takes to move cargo, while cost and revenue measures refer to how much it costs to use the required facilities to move cargo and the estimated total revenues and income.
3. A system needs to use a set of balanced measures that present financial and non-financial indicators. Bichou (2007) argued that quality and time measures present non-financial information for port managers. Hence, time measures have been applied in Chapter Five in developing DAPEMS for this purpose. Revenue measures will be integrated into the system for providing financial information for the port managers.
4. Providing reliable quantitative information for productivity, cost and revenue performance helps managers to improve their port performance (UNCTAD, 1976).

5. As discussed previously in the literature, current measurement systems rely on financial principles which are considered as a sole measure in most systems (Maskell, 1991; Lee and Billington, 1992; Barker, 1996).
6. In Damietta port, financial gains can be achieved through reducing time. Cost which can be saved due to reducing times can be used as a performance indicator in determining the port performance. It is commonly known as dispatch money.
7. Financial principles help the port managers track port performance on the chosen key performance variables.
8. In ports, demand is differentiated by time of day, day of week, type of cargo, speed, and so on. It makes it more difficult to analyse and forecast demand using only time measures. There is a need to understand the way in which facilities satisfy these needs in term of revenue.
9. Efficient and cost-effective infrastructure is a critical determinant of a port's competitive advantage. There is a need to understand and analyse the sources of port costs and revenues.
10. DPA and all other Egyptian ports have no formal system to determine total costs and revenues. Ports have to submit all revenues to the Financial Ministry and receive all their expenditures from the Ministry of Transport. Hence, DAPEMS aims to add visibility to revenues created by the port.

Flexibility measures need to be considered in DAPEMS for the following reasons:

1. It helps ports' managers and directors in choosing a suitable port strategy (UNCTAD, 1985).
2. It helps to cope with any handling technique. The purpose is to handle a fluctuating traffic demand.
3. Flexibility measures helps to provide a contingency plan in ports.
4. It helps to introduce new philosophies in managing ports' operations, such as partnerships and strategic alliances (Marlow and Casaca, 2003).
5. Port infrastructure design and port planning requires to consider flexibility measures (Taneja et al., 2010b). It aims to reflect the strategic objectives of the port authority that should be considered in the master plan.

In this Chapter, DAPEMS has been extended to integrate more measures, including port revenue measures and flexibility measures, to understand how port facilities and resources are used. The port managers can then take corrective actions to prevent the under-utilisation of facilities. The system also helps to show how intensively facilities are being utilised, so that the port managers can decide when extra facilities are needed, and when current facilities should be developed. In addition, it helps to determine the quality of the services being provided to both the ship owners and the shippers.

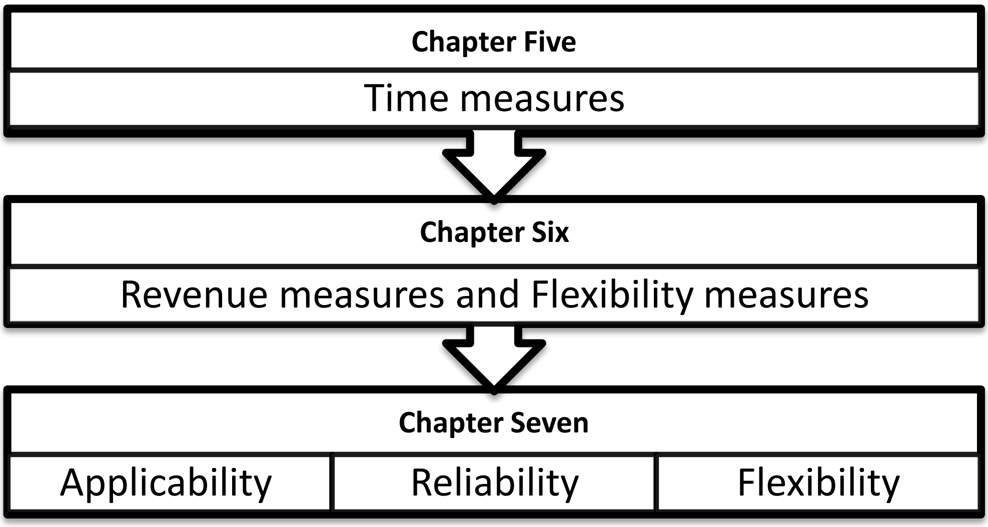


Figure 6.1 –The Extension of DAPEMS

Figure 6.1 shows the sequences of extending DAPEMS. The system has been developed in Chapter Five using time measurement. In this Chapter, the measurement system is developed and integrates revenue measures and flexibility measures. The three measures clarify how the improvement in the port performance may cause financial gains or losses to all the port participants. In this way, the analysis of DAPEMS has been conducted. The system applicability, reliability and flexibility, as featured, will be discussed in Chapter Seven.

6.2 Cost/Revenue Measures

It is important to differentiate between costs from the port’s perspective and the costs from the port clients' perspective. Only the cost from the port’s perspective will be discussed and considered in DAPEMS, because the measurement system is developed to help port management to control port operations and performance. Figure 6.2 shows that the cost from the port's perspective has two dimensions; port costs and the port revenues. DAPEMS considers only port revenues with no regard to port costs. This is because the port's expenditures are paid by the Egyptian government and there is no data available for the port's costs. Also, developing the port infrastructure and facilities, workers and managers’ wages and other costs are determined in advance because the port is considered as a governmental unit or agency.

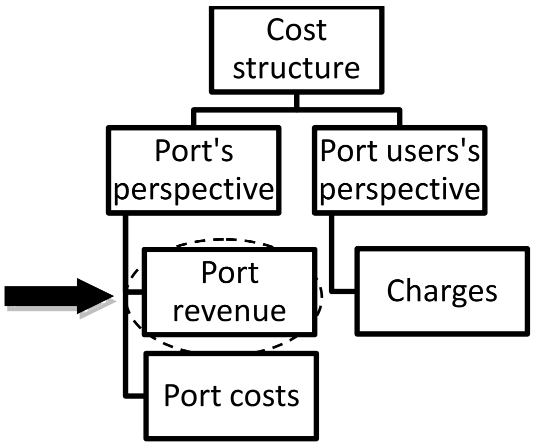


Figure 6.2 – Different Costs Perspectives

6.2.1 Cost Structure from Port's Perspective

As mentioned before, the cost structure from the port's perspective has two dimensions: port costs and port revenues. Many studies have discussed the need for a profound knowledge of the cost structure of port activities, the behaviour of costs in ports, the sources of revenues and the cost when the ship stays in the port.

The literature review shows that most research has calculated the key cost indicators rather than port revenues (Tovar et al., 2002). Cargo handling has received most attention as it represents more than 80% of the bill for a ship in port (Tovar et al., 2002, Ramos-Real and Tovar, 2010). The following part reviews those studies carried out to calculate both port costs and port revenues.

6.2.2 Port Revenue

As discussed earlier, many studies have been carried out to calculate the cost function. However, few studies calculate the port demand and revenue function (Talley, 2007).

UNCTAD (1976) quantified the financial indicators to calculate 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. Few suggestions were made to increase port revenues, such as increasing tariffs, attracting more users through promotions, increasing productivity and minimising variable costs. However, the focus was on the revenues generated while a ship is only at berth. Also, the study did not consider those revenues generated from warehouses and storage and clearance. UNCTAD (1979) explained that ports generate revenue from payments received from port clients who pay for the services provided. The services provided require the use of assets and facilities, which in monetary terms are known as port charges.

Kim and Sachish (1986) applied a revenue function suggested by Braeutigam et al. (1984) to calculate revenues received by containerised handling at Haifa port. They assumed that tariffs charged are regulated. However, they focused on calculating revenues received from containerised cargo at the port with no regards to other types of cargoes. Also, they calculated revenue received from handling operations, neglecting other sources of revenue such as warehousing and storage, and berthing. The following function has been applied by Kim and Sachish (1986):

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

Where: OR^{t} is the operating revenue for year t

CONt is the revenue with respect to containerised output handling

Martinez-Budria et al (1999, cited by Wang et al., 2002) applied DEA to examine the efficiency of ports in terms of revenue obtained from the rent of port facilities. Labour expenditures and depreciation charges were the main inputs in the model. However, they did not take into consideration other sources of revenue, such as berthing charges and pilotage.

The World Bank (2006) focused on the importance of calculating operating revenue in a port to determine the level of revenue risk. It identified the revenue sources, including port dues, equipment rental, services for ships such as bunkering, estate revenue, cargo handling and packaging. However, it did not show how to calculate port revenue in practice.

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 will attract more ships to call. However, they did not explain how revenues can be calculated in practice, nor the sources of revenue.

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 increases or decreases over time. He claimed to use the values of standard performance indicators to maximise profits. Different functions have been developed, including an economic production function, economic cost function, demand function, profit function and resource function.

Theys and Notteboom (2009) discussed that expected cost for future operations depends on energy prices and labour costs. On the other hand, expected revenue depends on future throughputs. They argued that future throughputs and energy prices are determined by the contract duration of concessions. However, they focused on concessions of the container terminal with no regards to other terminals. Also, they aimed to determine expected revenue in the future rather than actual revenue.

Tongzon (2009) explained that port charges vary according to a port's nature and functions, which in turn affects port revenue. He discussed two types of revenue sources, including ship-based types and cargo-based types. The focus was on port charges as criteria for port choice. However, he did not show how port revenue can be calculated.

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, such as US West coast, affect port revenue. Hence, they suggested encouraging investment in port ownership, leasing and construction. Emerging cooperation between ports was another suggested strategy. They argued that lower throughput due to the financial crisis was beneficial as it reduced congestion in ports. However, lower throughput refers to lower productivity and in turn, lowers performance. Table 6.1 summarises the main revenue functions developed for the port sector. It shows that few revenue functions have been developed.

Table 6.1- Revenue Functions for the Port Sector

Year	**Author**	**Objective**	**Function developed**	**Inputs**
1976	UNCTAD	Increasing port revenue	-	Ship revenue/ Cargo revenue
1986	Kim and Sachish	Containerised handling	Marginal revenue	Port tariffs
1999	Martinez-Budria et al	Port efficiency	DEA	Rent of port facilities
2006	Le-Griffin and Murphy	Container terminal revenue	-	Container handling productivity
2010	Pallis and Langen	Port throughput	-	Volume/Traffic

6.3 Port Revenue Consideration

Increasing the total time that cargo stays in Damietta port or in any other port 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 for 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:

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

These cases above provide 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 the cases above. Following UNCTAD's analysis of financial statements in ports (1979), equation (19) can be used to calculate the port revenue from operation time OT and it can make a balance between the above cases:

$$\text{Port revenue} = \alpha * \text{no. of handled tonnes} * \text{elapsed time} \qquad (19)$$

(Where α refers to a constant tariff)

Talley (2006b) developed an equation to calculate the annual total revenue in ports as follows:

$$\text{Port revenue} = (\text{port charge per unit} * \text{annual bulk throughput}) + (\text{port charge per container} * \text{annual container throughput}) \qquad (20)$$

Talley (2007) developed another equation to calculate port's profits as follows:

$$\text{Port profits} = \text{port charges} * \text{Port throughput} - \text{minimum cost} \qquad (21)$$

Equation (21) shows that increasing the volume handled in the port leads to an increase in port revenues. In Egypt, handled volume depends on how long it stays in the port according to the decrees set by the Egyptian Ministry of Transport. Damietta port charges a certain tariff per tonne per hour. UNCTAD's equation (1979) shows both performance dimensions: effectiveness and efficiency. Figure 6.3 shows that the effectiveness is the ability for Damietta port to attain the objective to handle as many tonnes as possible. This will improve the competitive position for the port and it will attract more users. The efficiency refers to how long cargo remains in the port. Hence, both dimensions of performance affect the port revenues and the tariffs paid by the port users. Keeping cargoes for shorter times and with reasonable costs will encourage the port clients to keep their loyalty towards the port.

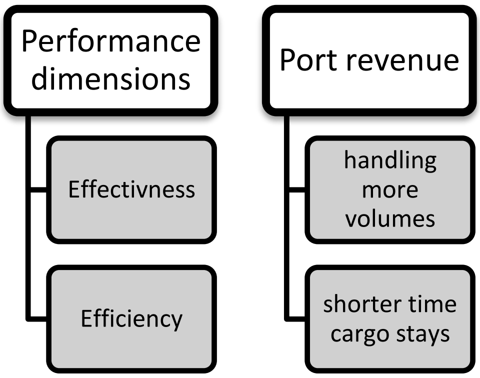


Figure 6.3 – Port Revenue and Performance Dimensions

In Damietta port, operations are very complicated and vary not only by number of calls, but are driven also by other factors such as handling operations, storage operations, total tonnes handled and handling rate per day. In DAPEMS, OT, TS and CT are used to simulate these operations. These models identify the amount of time needed to accomplish the required operations in the port. The time equations show how time is spent on a given operation.

For example, the OT equation shows how long it takes in loading and discharging. The OT equation can be used to calculate the revenues as time is an important element in the equation. The port already has data about total revenues received by the time a ship stays in port. The contribution is to figure out how much revenue can be generated from OT as the port itself has no clear figure, because a private company, DCHC, is responsible for loading and discharging operations. The system aims to provide the port managers with a more visible view concerning their revenues.

If port clients are satisfied with the service level provided in terms of time, they will call again at the port. Then, the port revenue will rise and the port planners can develop their port to compete with other ports. Also, the port revenue varies with time spent in the port. Tariffs are costs for the port clients, but at the same time, they are returns for the port as follows:

1. The costs of operations time at berth OT are income for the port in terms of loading and discharging fees.
2. The costs of time spent by ships in the port TS are income for the port in terms of berthing fees, port state control fees, towage fees and pilotage fees.
3. The costs of clearance time CT are income for the port in terms of agency fees, brokers and intermediaries charges.

It is important to know that tariffs paid by clients for the port itself are based on actual capacity rather than normal capacity. The actual capacity is used for the following reasons:

1. Actual capacity refers to highest activity level at which the port can operate with an acceptable degree of efficiency, taking into consideration unavoidable losses of operating time (i.e., vacations, holidays).
2. Actual capacity uncovers the cost of unused resources. It differentiates between the costs of resources *available* from the cost of resources actually *used* for a particular purpose.
3. The use of actual capacity provides accurate fixed overhead rates for each activity, because it excludes the cost of unused resources costs.

1- 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 ships 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 are handled in Damietta port, and how long cargos spend in the port. Following UNCTAD's equation (1979), equation (22) was developed to calculate the port revenue from OT:

$$\text{Port revenues from OT} = \alpha * \text{total handled tonnes} * OT \qquad (22)$$

Where:

α : It is a constant value. It refers to tariffs that port clients should pay. Tariffs are set by the Ministry of Transport in Egypt. 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, the α value includes the following elements: loading and discharging fees per tonne per hour.

For TS, the α value comprises the following elements: port and light fees, towage (in and out) fees, pilotage (sea and port pilot) fees, moor and unmoor fees and port state fees.

Total tonnes handled : is an independent variable and as the number of tonnes handled in the port increases, total revenue increases.

OT : is an independent variable and it refers to the operational time required to achieve loading and discharging operations.

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 the 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.

2- 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. 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 the total time a ship stays in the port (TS) that depends on both how long it stays and on the gross tonnage (GRT). Tariffs for TS are based mainly on one element namely port and light dues that 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.

Actually, revenues from TS include other elements such as towage fees, pilotage fees and port-state fees. However, interviews with the port managers proved that these elements have very low values and have little effect on revenues generated from TS. Table 6.2 shows how the port revenues can be generated from TS for all types of ships. 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 is applied in other ports such as Alexandria port.

Table 6.2- Revenues from TS Tariffs

TS revenues	Tariffs	(tonnes)	(time)
Port Dues	0.21 $	GRT	--
Light Dues	0.05 $	GRT	--
Wharfage Dues	0.0125 $	GRT	OT
Cleaning Fees	120 $	--	--

3- Port revenue from CT :

Clearance charges vary according to tonnage and are not time dependent. They are known as agency fees include the following elements:

1. Post office fees
2. Arabic translation fees
3. Fees for crew permission documents
4. Car rental
5. Telecommunication costs
6. Photocopy fees
7. Motor boat rental
8. Customs, immigration office, medical insurance fees
9. 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 is made by the help of calling a custom inspector during the port visit.

Table 6.3- DAPEMS

DAMIETTA

Performance Dimensions	Category	Sub-category	**Type of Cargo**	**General Cargo**	**Dry Bulk**	**Liquid Bulk**	**Containers**
Efficiency Dimension	Time Measures		OT	OT_{gen} = - 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	$TS_{gen} = OT_{gen} + 2SD_{gen} + BT_{gen} + UBt_{gen}$	$TS_{dr} = OT_{dr} + 2SD_{dr} + BT_{dr} + UBT_{dr}$	$TS_{liq} = OT_{liq} + 2SD_{liq} + BT_{liq} + UBT_{liq}$	$TS_{con} = OT_{con} + 2SD_{con} + BT_{con} + UBT_{con}$
			CT	CT_{gen}	CT_{dr}	CT_{liq}	$CT_{con\ (loaded)}$ - $CT_{con\ (empty)}$
	Revenue Measures		Revenue from OT/month (REVOT)	α_{gen} * no of tonnes* OT_{gen}	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)				
			Revenue from CT/month (REVCT)	β_{gen} *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

TS revenues	Tariffs	(tonnes)	(time)
Port Dues	0.21 $	* GRT	--
Light Dues	0.05 $	* GRT	--
Wharfage Dues	0.0125 $	* GRT	* time
Cleaning Fees	120 $	--	--

Effectiveness Dimension	Total Tonnes Handled	Total Tonnes Handled	Total Tonnes Handled	Total Tonnes Handled

Keys used in DAPEMS

1. TS = total time a ship stays in the port
2. CT = clearance time
3. OT = operations time
4. NCS = number of calling ships
5. BO = berth occupancy
6. TTH = total tonnes handled in a given period
7. LDR = loading/discharging rate
8. ST = storage
9. GRW = gross tonnage
10. α = tariffs set for loading and discharging
11. β = tariffs set for clearance cargo
12. REVOT = revenues generated from OT
13. BT = berthing time
14. UBT = un-berthing time
15. SD = standing time
16. REVTS = revenues generated from TS
17. REVCT = revenues generated from CT

6.4 Flexibility Measures

As performance measures, flexibility is important as it deals with how the port can cope with rapid changes. In port studies, flexibility has many dimensions and different flexibility measures have been applied according to the purpose of measurement. Table 6.4 displays some flexibility measures that are commonly applied in ports.

Table 6.4 – Flexibility Measures in Port Studies

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

UNCTAD (1985) recommended providing and applying different plans in ports to allow a prompt response to changing demand, 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 port capacity in case of the growing traffic, and to provide an 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. It is argued that investment plans should properly be developed in association with contingency plans in order to provide different solutions, including for example:

1. Hiring mobile cranes from outside the port
2. Hiring additional contract labour to increase the average number of gangs per ship
3. Opening up additional storage areas under customs bond either within or outside the port
4. Hiring additional trucks and trailers for transport to storage areas
5. Speeding up the handling rates
6. Reducing ship turn-around time
7. Developing separate specialised facilities, or developing multipurpose facilities.

Chlomoudis and Pallis (1998) claimed that ports need to rely on innovation, knowledge, information and planning to meet unpredictable changes. Hence, ports need to change their organisation, infrastructure and daily functions. In other words, ports need to be changed from a gate for loading and unloading cargoes, into a logistics platform. They argued that the logistics platform helps to provide operational flexibility. It aims to integrate ports into a production-transport distribution chain. This helps ports to reduce the time ships spend in ports, to increase ports' productivity, to supply added value services, and to apply advanced technologies. This requires ports to change their operating methods, administrative procedures and the technological infrastructure.

Chlomoudis and Pallis (1999) focused on the necessary changes in the port management to achieve an effective operation and to increase port capacity. The port management should be viewed as a system that combines markets, technologies and scientific management. The market aspect is concerning those strategies that should be applied to balance supply and demand in ports. Regarding the technologies, it refers to investments in equipment and labour. The scientific management aims to provide standardised port services in order to achieve economies of scale. They recommended any port should have regular maintenance of the port infrastructure, sufficient storage of large quantities, and reliable handling equipment to meet an increasing demand.

Fourgeaud (2000) refers to port flexibility as adaptability. It refers to the port's ability to increase its capacity to fit clients' needs. Suitable and maintained handling equipment, well trained workers and appropriate and well managed storage areas can, for example, influence the port's adaptability to cope with an increase in traffic and volumes. To determine a port flexibility measure, there is a need to discuss the port's ability to deal with changes.

The port's ability can be seen in terms of port capacity output. Fourgeaud distinguished between nominal capacity output and commercial capacity output. The nominal output is not suitable in the port industry because it does not take into consideration these factors that affect the port's flexibility, such as weather conditions, time spent in stowage, handling time, berthing time, repairing time and bunkerage. Hence, he argued that a commercial capacity output is more relevant as it considers previous factors. The argument is that flexible working time influences a port's capacity and in turn affects its flexibility to cope with the dynamic environment. In addition, the port's ability to cope with environmental changes can be seen in terms of average cargo dwelling time. Dwell times can be a result of shortage in storage areas, shortage in handling equipment, port congestion, clearance time delay, the level of automation of cranes, unproductive moves. Berth flexibility is also required to efficiently accommodate the number of calling ships. It can be used as a parameter to measure port performance. When the number of berths increases, waiting time deceases and the port flexibility increases to accommodate an increase in traffic and volumes.

Other flexibility measures can be used in measuring port performance, including product density, product characteristics, safety considerations, environmental considerations, dusty products and heavy-to-handle products, and restricted working time (shifts scheduled at fixed time). These measures may affect the port's ability in terms of lower handling rates and consequently it affects its performance and ability to compete with other ports.

Notteboom and Winkelmans (2001) claimed that port managers should focus on economies of scope instead of economies of scale in order to cope with the changing market environment. This explains why shipping lines expanded their scope to include terminal operations and hinterland transportation. They 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. The port's reputation, commercial attitude and the culture can also be used to represent the port's adaptability through developing core competencies.

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. Flexibility is a subset of agility (Kumar et al., 2008). Ports can be agile if they are characterised as:

1. Infrastructure and layout that meet trade requirements
2. Information systems
3. New management philosophy
4. Human elements
5. Intelligent knowledge
6. Offering innovative services
7. Partnerships and strategic alliances

They argued that ports need to be lean in order to be agile. Ports can be lean through making the best use of available resources, reducing all wastes in the information, documentary and physical processes and providing perfect customer services. They suggested that some flexibility measures can be used in measuring operational performance in agile ports, such as: level of damages in the shipment, lead time to service delivery, customers' complains, information accuracy, and notifications of any changes in the multimodal transport. Modern ports must address high levels of flexibility and adoptability, closer integration with other modes of transport, better management strategies and more efficient labour mobilisation and participation (Chlomoudis et al., 2003).

Tongzon and Heng (2005) claimed that port adaptability can be considered as an important determinant of port competitiveness that can be used in formulating effective planning and strategies. They applied principal components analysis to establish a port competitiveness index, and then regression analysis was used to examine the effects of the determinants of port competitiveness. Eight determinants of port competitiveness were proposed, including:

1. Port adaptability to the changing market environment: changing customer needs impose new roles for port authorities to adapt their service levels provided in ports.

2. Port operation efficiency level: Tongzon and Heng argued that a ship's time is an expensive commodity that requires speeding up the handling rates and reducing a ship turn-around time. This leads to an increase in productivity, a measure of the efficiency of port, and to obtain competitive advantage.

3. Reliability: adherence to shipping lines' schedules, shorter operation times, fewer equipment breakdowns, and less damage and losses help port operators and port authorities to increase port reliability. It influences port performance and consequently port competitiveness.

4. Port selection preferences: ports may lose their important shippers and carriers. This happens when clients have rearranged their service networks or have engaged in new partnerships with other carriers.

5. Depth of the navigation channel: ports with sufficient water depths in the access channel are able to accommodate larger ships. This helps a port to survive in a highly competitive market.

6. Landside accessibility: ports which are linked with good landside connections provide carriers and shippers with more options to move their cargoes. Connections need to be safe, quick and efficient. Port accessibility is used in port selection.

7. Product differentiation: ports compete to offer value to their users and quality services. It is called economies of scope.

8. Port cargo handling charges: port charges are considered a significant part in the transportation costs. The lower port charges, the high port competitiveness.

Jara-Diaz et al. (2006) claimed that a port has many stakeholders and operations which require high flexibility in terms of co-ordination between them. They focused on co-ordination between labour, space, facilities and equipment in port operations, which is divided into three stages: ship-oriented operations, cargo-oriented operations and intermodal operations. Shipbrokers are responsible to co-ordinate most of the services required by ships, stevedores companies take care of the cargo handling operations, and the freight forwarders coordinate the intermodal operations.

They further argued that a port is a factory that provides services (inputs) to receive, dispatch and deliver cargo (outputs). The inputs are labour, space, facilities and equipment, and the outputs are the cargo movements. The optimal combinations of the inputs to move different combination of the outputs refers to the port's flexibility. The argument is that a port has to have these inputs regardless of the kind of goods handled and the volume of traffic.

Diaz-Hernandez et al. (2008) focused on cargo handling flexibility because it involves all activities related to the movement of goods inside a port. Cargo handling flexibility takes two forms, namely labour flexibility and equipment flexibility. Skilful workers and highly technological equipment increase loading and unloading speed, reducing the total time cargo remains in ports, increasing handling safety, and reducing average costs due to economies of scale. They argued also that improvements in information systems help a port to programme a large percentage of ship arrivals. A combination of labour, equipment, information systems and stevedoring companies can be used as indicators for measuring cargo handling flexibility. They may increase the efficiency of cargo handling in a port system.

Notteboom and Rodrigue (2008) argued that increasing a terminal capacity can be considered as a major concern to provide flexibility to global supply chains. Raising traffic and volumes may result in major delays and it requires a port to have a high level of flexibility to cope with changes. This can be achieved through proper port planning, providing reliable handling equipment, sufficient storage areas and developing multi-port gateway regions.

Other flexibility measures were applied in ports such as slot sharing arrangements where carriers purchase slots in other carriers' ships to provide service flexibility (World Bank, 2007), improving the capability of port administration, pricing flexibility that affects the terminals' level of traffic and throughput, flexibility of asset use, flexibility of labour use by stevedoring companies and flexibility in the regulation system to cope with low demand situations.

6.5 Flexibility Measures and Port Performance

In ports, traffic growth and increasing volumes handled refer to the port's ability to attract financial resources for investments in ports (Pallis and Langen, 2010). Many ports promote their investments in infrastructure in order to improve the operational processes, customer service, handling techniques, and intermodal connections (Pallis and Syriopoulos, 2007). It is argued that it is a causal relationship between a port's performance and port traffic. Tongzon and Sawant (2007) argued that ports with deep water harbours and extensive areas of land can attract a significant amount of traffic.

Yeo et al. (2011) developed a framework for evaluating the structure of port competition, including different determinants such as availability which refers to berth availability and service delivery time to meet heavy port traffic.

Hence, a port’s flexibility should be considered in the infrastructure design and port planning (Taneja et al., 2010b). Planning refers to the master planning that reflects the strategic objectives of a port authority and the requirements of port users and operators. Taneja et al. (2010a) argued that a port master plan aims to meet the objectives of the port as it includes an adaptable plan and a contingency plan, to change over time in response to changing environment. 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 and developing a multipurpose port handling for all cargoes. They also claimed that flexibility can enhance a measurement system through providing flexible alternatives to cope with prediction of the uncertain future. As a performance measure, flexibility can be defined as optimising the movement of cargo and reducing turn-around time of ships.

In Damietta port, traffic and volumes are also crucial elements that influence the port performance because the port capacity and design is dictated by ship design and cargo size and shape (Taneja et al., 2010b). Any changes in these elements require the port operators and the port authority to cope with changes. As discussed earlier, Table 6.4 shows that studies of port flexibility focus mainly on port capacity in term of reducing turn-around time and controlling and managing the operations time. OT and TS developed previously as time measures can be used to assist in measuring flexibility.

For traffic, TS can be used to measure the port’s ability to accommodate a high number of ships calling at the port, in relation to the number of calls. Controlling TS in fluctuating traffic demand refers to the port’s ability to keep ships for a shorter time.

For volumes, it is related to how long it takes for loading and unloading cargo, where OT can be used to measure the port's ability to handle more volumes with no real increase in the operation time. It depends on labour skills, equipment capacity and availability, berth availability, and storage availability. Unavailable and improper equipment, for example, can lead to more standing time without operations. Integrating flexibility measures into DAPEMS helps to cope with the complexity in the port environment.

In DAPEMS, flexibility measures will be added to 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's construction (Taneja et al., 2010b). In the second layer, flexibility is concerned with 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 states that service flexibility is concerned with the ship turn-around time. These layers help to incorporate the flexibility measures into DAPEMS. Table 6.5. shows how the flexibility measures take place to calculate the port ability to respond to any changes.

Table 6.5. – 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 6.5, the port flexibility can be measured through operations flexibility and service flexibility. 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 shown in Table 6.5, 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 an increase the time required for loading and unloading shipments and to an increase in other forms of time such as clearance time. Controlling these times to the minimum refers to operation flexibility. There are many flexibility dimensions that can be used to control these times as follows:

1. handling rate (hr)
2. handling methods (hm)
3. equipment productivity (e)
4. storage availability (sa)
5. labour productivity (lp)
6. volumes handled (vh)

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

1. berth length (bl)
2. berth throughput (bt)
3. handling rate (hr)
4. labour productivity (lp)
5. administrative procedures (ap)
6. shift working-time (sw)

For a short time plan, equation 23 can be considered in the investment plan, mater plan and contingency plans in Damietta port. It helps to assess the port's ability to cope with changing demand. Planning and controlling these flexibility dimensions lead to higher level of flexibility utilisation. It requires the port authorities to adopt their time-based strategies and procedures to cope with changeable demand.

$$\text{Port Flexibility (PF)} = f\,(hr, hm, e, sa, lp, vh) + f\,(bl, bt, hr, lp, ap, sw) \qquad (23)$$

For a long time plan, top managers at ports need to be involved from the beginning of the implementation of operations to provide an agile port, that requires a new approach to quickly adapt the services provided (Marlow and Casaca, 2003). Controlling these dimensions requires an information distribution centre, landside accessibility and network connections, technology, new working philosophy and strategic alliances with other ports.

Marlow and Casaca (2003) claimed that agile ports can be flexible, responsive, adaptable, and knowledge centres. Flexibility can be viewed as a subset of agility (Lummus et al., 2005). Chlomoudis and Pallis (2004) claimed that a port which has multiple independent service providers, can offer greater flexibility and adaptability to its clients. They argued that port planning, management and operations should apply adaptable strategies to provide integrated port services according to its users' context and situations. Das (2011) claimed that any organisation must strategically plan for both volume/capacity flexibility and customer service level flexibility to respond quickly to future growth.

6.6 DAPEMS Analysis

Table 6.3 shows the extension of DAPEMS. The system aims to help Damietta port management to predict, manage and control port performance using two measures: time and revenue. It provides port management with feedback about two-performance dimensions (Stainer and Stainer, 1997): (1) efficiency in terms of how long cargo remains in the port, and the port revenues, where time and revenue measurement categories have been used; and (2) effectiveness in terms of how many tonnes are handled in the port.

The two measurement categories have been developed: (1) to cope with the port strategy by defining the metric used to quantify in-port operating environment; and (2) to help the port managers achieve the goals by satisfying the port users with reasonable charges and quicker cargo throughput than their competitors. For flexibility measures, different flexibility dimensions can assist a ports' managers in their planning and managing their facilities and resources.

The formation of DAPEMS can be analysed at three different levels (Neely et al., 1995) to examine whether the system design is appropriate or not to achieve the port's strategy and goals.

The first level of analysis concerns the individual performance measures used in the system, time, revenue and flexibility measures that simulate the operations in the port, as these measures reflect the key dimensions of the port performance. Also, it concerns the benefits that these measures provide. A time measure has been used as it is a source of both competitive advantage (Stalk, 1988) and the fundamental measure of port performance. A time measure has been employed as a means of competitive advantage to reflect the efficiency dimension of performance. The revenue measures provide a visibility about revenue received by the port from tariffs. In addition, the system is more flexible in terms of short-term and long-term actions to respond to any change in the operating environment that affects port performance. Flexibility measures support port managers in their investment plans and strategies to cope with unexpected fluctuations in traffic demand and volumes.

The second level of analysis is concerned with the performance measurement system as an entity to determine if all the appropriate variables used in the system have simulated the port operations such as how long operations take, how long ships stay in the port (TS) and clearance time (CT). These variables represent internal inputs, such as berth occupancy and handling rates; external inputs, such as total tonnes and total number of ships calling the port; financial inputs, such as port revenues; and non-financial inputs, such as clearance time that is based on a human factor. However, there are other variables that may influence the port performance. Those variables are recommended to be considered in further research.

Also, analysing the integration between measures shows that the design of the measurement system starts with a time measure calculation. In turn, it helps to calculate revenues received from OT. In other words, a revenue measure cannot be calculated without or before a time measure calculation. Moreover, each performance measure has a clear purpose as a time measure gives feedback about the duration of cargo remaining in the port, while a revenue measure provides a financial report about estimated revenues.

Also, a flexibility measure provides port managers with those factors that should be taken into consideration when planning and managing a port's facilities, such as berth length, administrative procedures and labour productivity. Reengineering and preparing a port investment plan, a contingency plan, a master plan and any other plans are relative to port revenue.

The analysis shows also that none of the measures used conflict with one another to make sure that the system design simulates continuous improvement rather than simple observation. Essentially, conflict does not exist between measures as the measures are integrated to determine port performance. This is because data collection and methods of calculating the performance criteria were clearly defined and the relationship between the key variables and OT has been examined.

The third level of analysis examines the relationship between DAPEMS and the port environment within which it operates to ensure that the system fits both the port's internal and external environments. For the internal environment, information such as the total time cargo remains in the port in the forms of OT, TS and CT and port profitability appeared to dominate the performance. For the external environment, the two measures used in the system match the port's culture because they represent the operating environment in terms of estimating OT in the port, and in turn they increase the competitive advantage for the port to compete with others. Different scenarios can be estimated using DAPEMS as follows:

1. Low OT and high handled tonnes
2. High OT and low handled tonnes
3. High OT and high handled tonnes
4. Low OT and low handled tonnes
5. High OT and high TS
6. Low OT and low TS
7. High OT and low TS

8. Low OT and high TS
9. High CT and high handled tonnes
10. Low CT and low handled tonnes
11. High CT and low handled tonnes
12. Low CT and high handled tonnes

When the total time cargo remains in port increases while total tonnes handled in the port decreases, this may be due to poor handling equipment or due to shortage of storage yards and warehouses. In this case, the port revenue will decrease, as the port will handle less volume and there will be no improvement in performance. Long-term actions are recommended that may lead to an increase the fixed costs as new assets and facilities are added.

The port management should compare OT, TS and CT with total tonnes handled in the port. The measurement system indicates how many tonnes are handled per type of cargo. It is important to compare total tonnes handled with time measures as it is a good indicator to determine if there is an improvement or not. The port management should determine where the problem is. Is it in OT, TS, or in CT.

6.7 Chapter Summary

DAPEMS was developed in Chapter Five using time measures. In this Chapter, the system was extended using revenue and flexibility measures. Table 6.1 summarised the revenue functions that have been developed in port studies. In DAPEMS, different revenue equations were developed to provide visibility about what the port earns. Flexibility measures were incorporated into the systems in three layers, including physical infrastructure, operations and services. Equation (23) displays these flexibility dimensions that should be considered by the top management in designing, renewing, planning, managing and controlling the port's resources. It aims to measure the port's ability to cope with change.

Chapter Seven
Reliability, Applicability and Flexibility of DAPEMS

7.1 Introduction

A variety of performance measurement systems have been developed using different techniques such as: econometric techniques, engineering techniques and financial techniques that include different inputs and apply different measures. The main concern is how far the developed performance measurement system is reliable and applicable.

In this Chapter, the following key characteristics of the developed system: reliability, applicability and flexibility, are explained. The purpose is to verify the empirical correspondence, meaning that the measures (time, revenue, flexibility) that have been chosen are related to the theoretical construct. Identifying the system’s capability helps to examine the usefulness and effectiveness of DAPEMS at Damietta port. Also, it aims to ensure that the system's outputs can be used to help Damietta port managers in their planning and controlling of performance. Figure 7.1 shows the sequence of the explanation of the system's reliability, applicability and flexibility. It shows that the reliability of DAPEMS will be explained from four aspects, while the system's applicability will be discussed in terms of generality, and the system’s flexibility in terms of uncertainty.

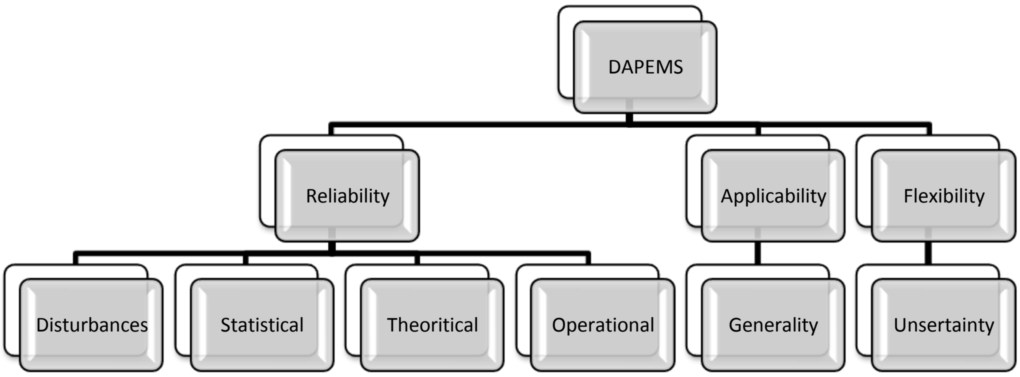


Figure 7.1- Examination Sequences

7.2. DAPEMS Reliability

There are many definitions of system reliability. However, those definitions are mainly concerned with system reliability as the ability to perform the main designed functions. Lincoln and Guba (1985) proposed four criteria for judging the soundness of qualitative and quantitative research as shown in Table 7.1.

Table 7.1- Qualitative/Quantitative-oriented Criteria

Quantitative	**Qualitative**
Internal Validity	Credibility
External validity	Transferability
Reliability	Dependability
Objectivity	Conformability

Source: Lincoln & Guba (1985)

They defined system reliability and stability as the consistency of measurement, or the degree to which the system measures the same way each time it is used under the same condition with the same subjects. The more consistent and stable the measurement system is, the more reliable it is. The consistency of the measurement system refers to the validity to use the system in the future to assess performance.

Sireci (2007) explained that reliability is considered as part of validity. He argued that reliability and validity refer to interpretations of test scores. For reliability, it concerns how consistent the scores are over time.

Brahma (2009) emphasised that measuring a theoretical construct comprises errors. Hence, testing reliability is required to assure the validity. He argued that reliability can be examined by the number of items and variables that define the scale because a measurement system depends on the extent of items and variables. Reliability means the consistency of the items that are used in the measurement process (Tongzon et al., 2009).

For validity, Shepherd and Helms (1995) argued that it exists when a performance measurement system is properly designed and implemented, reliable and accurate data have been collected and the system is used easily by managers. They set four procedures for testing validity. Firstly, face validity that is based on the subjective evaluation of the researcher. The second procedure is the content validity, which concerns the sampling adequacy. Criterion related validity is the third procedure. It concerns how the measure can predict future outcomes. Finally, construct validity is composed of many types of validities such as trait validity and convergent validity.

Mentzer and Flint (1997) argued that validity in research is actually a hierarchy of procedures to ensure that the research outputs are stated with some confidence. They argued that validity is composed of four components: internal, external, construct and statistical conclusion validity. Internal validity provides evidence that the relationship between two variables is causal. They defined the external validity as the degree to which the research findings can be generalised to the broader population. They argued that external validity is based on an appropriate sample size and adequate response rates.

Mentzer and Flint (1997) argued that reliability is important as it assures the consistency between measures. Without reliability, no system can be tested against validity.

Mark et al. (2002) discussed the criterion-related validity, which comprises two types of validity: concurrent validity and predictive validity. The criterion-related validity refers to the degree of effectiveness with which performance on a test or procedure predicts performance in a real-life situation.

Trafford and Leshem (2010) claimed that a deductive approach provides conclusions which are high in reliability and low in validity, and consequently, it becomes possible to generalise conclusions. Reliability is present if the conclusions can prove the hypotheses. It can be concluded from these previous studies and research that system reliability exists if it has the following features:

1. A system has a hierarchy of procedures
2. A system has an appropriate sample size
3. A system has a number of relevant and relative variables that define the scale
4. A system shows a relationship between variables
5. A system has a causal relationship between its variables
6. A system provides generalised findings
7. A system is easy to use

Considering the reliability of DAPEMS against these features listed above, the following part discusses the system reliability in case of disturbances at Damietta port, in terms of statistical design, theoretical structure and operational reliability.

7.2.1 System Reliability in the Process of Disturbances

Ports face different factors that may lead to disturbances, disasters and risks, which can affect the overall performance. Hence, international codes, conventions and recommendations have been set by many organisations such as the International Maritime Organisation (IMO) as guidelines for port authorities, operators and managers. These international instruments include, for example: The Awareness Preparedness for Emergencies at Local Level for Port Areas (IMO, 1996) and Code of Practice on Safety and Health in Ports (ILO, 2003). These instruments aim to provide best practice to face any disturbance which may occur.

Ramage (2003) distinguished between two international instruments, the International Safety Management (ISM) and the International Ship and Port Security (ISPS) codes. The security instrument concerns risks associated with protection against an act of disturbance and damage. Safety instrument concerns risks associated with protection against accidental disturbance and damage. The focus was on criminal, piracy and terrorist activities. He argued that ships and containers can be used to carry hidden weapons or dangerous cargoes for terrorist purposes. However, he did not show how such a framework or system can cope with disturbance and damages in a port. Also, the impacts of disturbance on operations have not been explained.

Koch (2003) addressed different precautions that affect the security of ships, port facilities, personnel security and cargo security. Getting reliable and accurate information prior to ship arrival is the main issue to implement security standards properly, such as cargo manifest information and the worker's identification cards. However, he focused on the security aspect rather than safety aspect. Various factors of disturbances have not been discussed. Also, the focus was on USA regulations with no regards to other countries.

Gkanatsas (2005) investigated the main sources of disturbances that affect the performance of the maritime transport system in ports. Environmental constraints were the main source of disturbances. It includes weather conditions such as snow and low visibility, and port infrastructure conditions such as access channels and lights. Gkanatsas focused on two types of delay being the main result of disturbances occurring in ports, namely terminal delays (port time) and routing delays (sailing time). He developed a system to model liner shipping schedules. However, his thesis focused on liner shipping with no regards to other ships calling at ports such as tramp ships. Also, only environmental conditions were considered, with no regard to other conditions such as political conditions and economic conditions.

Factuar (2005) discussed various port management practices, systems and approaches applied in ports related to safety, security and health disturbances, such as Coastal Management Approach and Environmental Management System (EMS). These systems considered ports as the main source of marine pollution. However, the focus was mainly on environmental factors that cause disturbances with no regards to other factors such as political factors.

The U.N. (2006) suggested an analytical framework for risk assessment and maritime security management in ports. It started to evaluate the current (ISPS) code that was developed by IMO. A risk-based framework consists of five steps, including defining risk, risk assessment, risk management, cost benefit analysis and decision making. Different models have been applied for each step. However, no single model has been recommended as a tool to assess risk and disturbances in ports.

The World Bank (2007) identified risks and disturbances confronting port operations. It explained six factors which may cause disturbances and risks for terminal operators:

1. Legal factors that arise due to changes in regulations and laws that organising port operations, such as tax law, labour law and security law.
2. Economic factors that arise due to inflation, wage and salary levels and exchange rate fluctuation.
3. Social and political factors that arise due to changes in geopolitical conditions, such as stability in national, regional and local governments.
4. Environmental factors that arise due to pollution, construction of marine infrastructure, accidents and dredging.
5. Traffic risks that arise due to operator's pricing decisions.
6. Force majeure factors that arise due to natural risks such as tidal waves and earthquakes, industrial risks such as fire, socio-political risks such as strikes and civil war, and risks of wars and armed conflict.

However, it discussed the risks and disturbances only from a financial perspective. Also, it focused partially on risks associated with terminal operations rather than risks associated with the operations of the whole port.

Bichou (2008) discussed risk assessment and management models applied in ports to face disturbances. Each disturbance source is represented by a predictor variable in such a system, and with variables ranging in frequency. Fault Tree Analysis (FTA), Event Tree Analysis (ETA) and Navigation Vessel Inspection Circular (NVIC) have been discussed in ports. Bichou developed a quantitative-risk assessment model to help port managers take corrective actions toward any risk and disturbance that may arise. However, attention has been given toward accidents as a main source of disturbance in port operations. Also, the focus was limited to container cargo.

Hunt (2009) claimed that moving cargo in ports is always associated with risks and can cause disturbances in operations. He classified disturbances as environmental, economic, social and political disturbances. Hunt argued that managers must look at ports as a subsystem of logistics systems, and this helps to determine whether disturbances arise internally or externally. Different disturbances were explained such as natural disturbances, strikes, riots and accidents where precautionary measures were recommended to be applied.

Mansouri et al. (2009) argued that system reliability refers to the capability of a system to provide acceptable results in the face of major disruptions. They discussed system responsiveness before and after facing disruptions. They categorised disturbances into four categories, including natural, organisational, human and technological factors.

For assessing the DAPEMS reliability, some disturbances can happen at any time due to unpredicted events. Hence, it is important not only to describe the system's procedures, but also to provide some means by which the unpredicted events can be expressed and monitored. It is proposed to adopt a performance assessment sheet to assess the system's behaviour. A performance assessment sheet involves four elements (Morcus, 2009; Mansouri et al., 2009):

1. Identification of potential disturbances which may occur at Damietta port.
2. Determination of the impacts of disturbances on the system.
3. Identification of the frequency of occurrence of potential disturbances.
4. Identification of acceptable measures.

The sheet is designed to include previous elements. For the first element, potential disturbances have been set based on the World Bank's classification of risks and disturbances in ports. This list of disturbances has been discussed with the port operations manager to add or remove any event. An agreement on this list was received by the port operations manager with two conditions that a disturbance should be dangerous and uncertain. If the event does not meet these conditions, it is considered as a non-disturbance situation.

For the second element, it is important to highlight that a disturbance may influence only an individual component of the system rather than influencing the whole system. For the third and fourth elements, the frequency of occurrence and the acceptable procedure to provide better actions have been discussed with the port technical office manager and the operations manager. Based on historical events, the frequency of events has been set to be low frequency, moderate frequency or high frequency.

Morcus (2009) argued that the reliability theory is concerned with the occurrence and non-occurrence of those factors that may lead to disturbances. In other words, a frequency of occurrence refers to a failure rate or mean time to failure which is considered as one of the most common of the system's reliability parameters (Yeo et al., 2011).

Table 7.2 shows the performance assessment sheet that has been developed for these factors that may lead to potential disturbances in Damietta port and which may contribute to affect the DAPEMS performance. Hence, there is a need to understand the nature of these factors that influence the system's performance. A performance sheet can be used accompanied with DAPEMS to cope with disturbance situations. Also, the sheet supports managers to decide to accept, continue or reject using the system.

Table 7.2- Performance Assessment Sheet

Elements	Potential disturbances	Effects on DAPEMS system	Frequency	Acceptable procedure(s)	Remarks
Potential Disturbances	Legal disturbances	No effect	Low	-	Accept
	Economic disturbances	Partial	High	Updating data	Continue
	Social and Political disturbances	Partial	Moderate	Operations time (OT) Time a ship stays in port (TS)	Continue
	Environmental disturbances	No effect	Low	Investigation	Accept
	Traffic disturbances	Partial	Moderate	Number of calls	Continue
	Force majeure	Whole	High	Port close	Reject

<u>Keys</u>

- Low frequency = occurrence once every five years
- Moderate frequency = occurrence once every year
- High frequency = occurrence more than once per year

- Partial = affect partially a component
- Whole = affect the whole system
- No effect = no effect on the system

Accept using the system

Reject using the system

Continue using the system with precaution

The response of the port operations manager at Damietta port to these potential disturbances, as shown in Table 7.2, is as follows:

1. For legal factors, disturbances are infrequent. The operations manager argued that this type of disturbance may occur approximately every five to ten years. This is because Damietta port is owned, operated and managed by the government. He accepts using the system in this type of disturbance.

2. The port operations manager agreed that economic factors frequently change due to many reasons, such as inflation and growth in wage and salary levels. These factors affect the prices at ports, for example, port charges and tariffs, port dues, storage expenses and taxation, which consequently affect port choice. The port manager recommends to continue using the system when the existing port tariffs have been updated with the new tariffs.

3. The port operations manager agreed that social and political factors are moderatly infrequent. This occurs when strikes occur occasionally in the port industry, which may cause a delay in handling cargo, increasing total time a ship stays in port and leaving cargo for longer time in warehouses and storage areas. He recommends continuing using the system as the OT and TS values can present any delay at the port as standing time is included.

4. For environmental factors, the operations manager claimed that these factors are infrequent because Damietta port sets strict rules towards marine pollutions and cleaning fees, which are obligatory for all ships calling at the port. The Damietta port director claims that the port is a clean port where many precautions take place to protect the land, maritime and air environments. The port has waste reception units, road cleaning vehicles, waste incinerators, drainage treatment stations, cleaning boats equipped with mobile skimmers for oil spills, a boat for reception of wastes and a waste reception station with a total capacity of 400 tonnes available 24 hours per day.

Also, the port is equipped with six meters high fences around the storage area, supplied with water nozzles for realising the dust pollution**.** Hence, the port manager accepts using the system in this type of disturbance.

5. The port operations manager focused on accidents, lack of equipment and congestion as the main traffic factors which may cause traffic disturbance. This type of disturbance may increase standing time, either due to lack of equipment or due to an accident. The operations manager recommends monitoring the TS value and its components which include standing time (SD). Also, he claimed that observing a number of calls is an acceptable procedure to monitor the port performance in case of traffic disruption.

6. For force majeure factors, Damietta port, like other Egyptian ports on Mediterranean Sea, closes occasionally during winter months, when, for example, tidal waves occure. The technical office and operations managers recommend not using the system, nor any other systems in this situation.

The performance assessment sheet supports DAPEMS in measuring the port performance during disturbances occurrence. It is recommended to observe OT, TS and CT during disturbances. Higher OT, for example, may be due to higher productivity and handling more volumes and receiving more ships. Also, it may be due to lower productivity where ships stay for longer time at berths or in the port, where handling rates slow down, where storage yards are congested and where the port operations become paralysed. As mentioned in Table 7.2, DAPEMS has the ability to perform its functions in disturbances, except force majeure disturbance. Bolton (2000, p.7) explained that the reliability of a measurement system is the chance that the system will operate to a specific level of performance under specified environmental conditions.

7.2.2 Statistical Reliability

Statistically, reliability can be defined as the ability of a model to detect the relationship between the response and predictors (Ware and Brewer, 1987). On the other hand, reliability can be tested in multiple regressions if random errors are independent and if random errors have a normal probability distribution (Stephens, 2004). Lamberson and Kaps (2004) explained that adding the unnecessary effects of non-significant predictors may increase the residual mean square.

For testing the reliability of OT regressions, it is important to highlight that multiple regression analysis can be performed either for forecasting purposes, or for identifying the best fitting model for the response. For the first purpose, coefficients indicate the estimated variation in the response. For the second purpose, regressions can be used to determine the significance of relationships between the predictors and responses. In Chapter Five, the following equations have been selected for both these purposes.

$$OT_{gen} = - 2054 + 47.8\ NCS + 0.00468\ ST + 28.5\ BO \qquad (3)$$

$$OT_{dr} = - 1110 + 51.2\ NCS + 0.00159\ TTH + 0.00622\ ST \qquad (6)$$

$$OT_{liq} = - 6 + 43.8\ NCS + 0.00215\ TTH - 0.0137\ ST \qquad (13)$$

$$OT_{con} = - 815 + 14.9\ NCS + 11.1\ BO + 0.0540\ LDR - 0.00285\ ST \qquad (17)$$

It is obvious that not all predictors have been included in all models, as some predictors are not significant to the OT (response). Adding a non-significant predictor could result in:

1. Making the relationship more complex between predictors and the response.
2. Making the results more questionable as errors of variance may increase.

Adding a non-significant predictor to the models leads to a low level of reliability, which is called poor reliability. Poor reliability exists if low-significance variables are added, or if multicollinearity exists. High multicollinearity and low significance means low reliability. Multicollinearity can affect the direction of the relationship between the response and predictors. Removing non-significant predictors will result in high reliability in terms of high significance and lower multicollinearity (Lamberson and Kaps, 2004).

In DAPEMS, multicollinearity has been considered by removing those variables that have a high correlation with other variables. Also, only significant relationships have been considered to ensure reliable best-fitting models. These procedures increased the degree of reliability of selected models.

In addition, regression models have a statistically high degree of reliability as errors are assumed to be normally distributed. Tongzon (1995) argued the reliability of the multiple regression models by assuming that errors are normally distributed. All regression analyses performed in Chapter Five provide models that entailed errors. Errors mean that the regression line does not follow through all the data, which are known residuals. One question is addressed: how can regression models be considered reliable if it has standard errors?

In the statistical theory, Baltagi (2005) explained that there is a problem to get the optimal estimation. He argued that the optimum refers to an unbiased estimator that measures the goodness of fit using variance. In other words, he refers that the unbiased estimator has less variance and has generally applicable results. Unbiased reliable statistical models, with the smallest residuals, are being selected when they can explain the variability in the observations. This is based on selecting those models where errors are close to zero. This means that there is at least one predictor that has an effect on OT. Also, the sampling error is acceptable as a large sample size can reduce errors to the minimum (Saunders et al., 2003).

In Chapter Five, stepwise regressions have also been carried out in order to find out the best explanation of all testable influences on OT. In this type of regressions, reliable and unbiased models have been selected by testing actual standard errors rather than relying on R-sq, f-statistics (Baltagi, 2008). These arguments show that the regression models selected for estimating OT are reliable as they are the best-fitting model with minimum errors.

7.2.3 Theoretical Reliability

As discussed earlier, consistency is an important element to assure reliability. DAPEMS has the following characteristics:

1. The system aims to measure Damietta port's performance in terms of the time cargo stays in the port.
2. TS and CT influence the duration of cargo staying in the port.
3. BT, UBT, SD and OT are parts of TS.
4. Regressions have been performed to find out the best fitting models for OT, where the predictors are NCS, TTH, BO, LDR and ST.

It is obvious that in each step, a number of measures have been considered. Each step has a different number of measures and the measures are also different within each step. These measures constitute the essence of the system. They contribute either in increasing or decreasing the consistency of the system, and consequently they affect the system's reliability.

Consistency can be improved through increasing the number of items and variables that can define a scale (Brahma, 2009). Currently, DPA applies limited measures and predictor variables to assess Damietta port's performance. These measures are NCS and TTH. As discussed earlier in Chapter Four, these measures unsatisfactorily evaluate the port’s performance. This is because other measures, which influence port performance have not been considered. On the other hand, according to Brahma (2009), the DAPEMS considers more measures that will result in:

1. More information about operations that influence port performance.
2. Explaining the cause of the problems that the port currently faces.
3. Assisting the port managers to determine the way to treat problems by identifying the area of deficiency.
4. The presentation of both sides: sea-leg side and land-leg side. This helps to measure overall port performance rather than partial measurement for certain terminals and operations.

These benefits can be obtained if more variables and measures are applied and integrated into such a system. DAPEMS can provide these benefits by including more variables. It can be considered as a controllable tool to manage complicated operations and activities in Damietta port. In other words, the above benefits increase the system's consistency as they cover many aspects in the port. The system has a high reliability if it has a consistency in terms of defining the settings at Damietta port. The system can cope with complexity in the port by identifying problems and providing more information about complicated operations.

The literature proved that using an adequate number of measures can help port managers and planners to take the right decisions as they will know more about the operating environment and problems. Tongzon (1995) claimed that few studies identified measures and factors that influence a port's performance. He argued that measuring port performance can be inconsistent if there is a lack of reliable information about all aspects of utilities in the port.

Fourgeaud (2000) argued that developing a reliable measurement approach requires a set of relevant indicators to provide accurate information of both land-side and sea-side. He focused on considering other factors to provide a reliable measurement of performance that meets with the port and shippers' requirement. Gray (2005) claimed that a variety of measures can reflect conceptual approaches to port operations and functions. Also, he emphasised that this is a common predicament for developing a valid framework of port performance measurement.

Bichou and Gray (2004) argued that a valid framework of a performance measurement system can be achieved by combining various factors that can provide more analysis for port managers. Cullinane et al. (2004) argued that port performance cannot be measured on the basis of one single measure. Marlow and Casaca (2003) insisted that considering appropriate measures in such a system will provide a reliable evaluation of a port's performance as it will meet a port's objectives. UNCTAD (1976) claimed that using various indicators and measures will result in rich data and information that help managers to observe the trend of their port performance. Taylor (2007) claimed that explaining statistically the behaviour of one dependent variable in terms of several independent variables always produces a much better fitting model.

However, different combinations of measures have been conducted. This is based on the purpose of evaluation either towards a partial assessment of certain operations and terminals, or for assessing overall port performance. As discussed in the literature, port performance has been measured against quay cranes, quay length and yard cranes (Wang et al., 2003), speed vessel and handling rates (Chung, 2003), berth occupancy, berthing time and un-berthing time (De and Ghosh, 2003), infrastructure and connectivity (Valntine and Gray, 2002), total volumes handled, ship size, crane efficiency, frequency of calls, location and number of berths (Tongzon, 1995; 2001).

Following the literature, DAPEMS has considered different measures in its steps. These measures have been considered to meet the requirements of establishing a relevant and reliable system because:

1. They present both sides: maritime interface and land interface.
2. They include these current measures applied in Damietta port: NCS and TTH.
3. They comprise more measures that have not been considered in Damietta port before: such as BO, LDR, ST, BT and UBT.
4. They have previously been considered by other researchers, but separately.
5. DAPEMS tailored a different combination of these measures.

This combination and steps provide visibility and control in the system. Visibility of the DAPEMS itself refers to the ability to observe the port status, outputs, resource usage and operations. DAPEMS control is the ability to incorporate all required inputs into the system and to observe the outputs that refer to performance indicators. By this, actions can be taken if the outputs are not satisfactory, as the system provides the port managers with a clear view of the complicated operations in the port. DAPEMS is reliable when it provides managers with visibility in order to control the port's status. The system can provide visibility in the following ways:

1. DAPEMS can provide two visible dimensions to improve port performance. One dimension measures the port efficiency using time and revenue measures. It helps to monitor the total time cargo stays in ports and estimates the port's revenues. Time measures provide non-financial information about the port performance (Bichou, 2007), while revenue measures provide financial information about the port performance. The second dimension measures port effectiveness by monitoring how many tonnes are handled in the port. Hence, DAPEMS's reliability exists as it provides a view of both dimensions of performance: efficiency and effectiveness.
2. Controlling OT, TS and CT would help to minimise the total time cargo stays in ports, and in turn, improve port performance. It meets the port's strategic objectives.

3. Monitoring port performance, in terms of the total time cargo stays in ports, helps the port participants in their actions. Stevedoring companies need to use modern handling equipment or to maximise the utilisation rates of current equipment. The port itself needs to invest in expanding the infrastructure such as increasing the number of storage areas, berth lengths and depths. Transport service providers need to use reliable and a sufficient number of vehicles to link the port with final destinations. The operations manager may need to increase the number of working hours per shift, or increase the number of workers per shift. All these aim to maximise port productivity in terms of the total amount handled in the port. The system can help in reviewing the current level of operations and whether it should be improved or not when there is an increase of duration of keeping cargo for longer times.

4. The system's reliability is concerned with the soundness of an investigation, and the cause and effect need to be internally valid. To demonstrate causality, two conditions should be met: the cause must precede the effect, and the size of the effect varies with the size of the causal factor. DAPEMS relies on predictor variables that have large impacts on port performance. These variables play an important role in determining port performance as they present the five groups of operations that have been developed by the researcher in Chapter Five. Any increase or decrease in these variables results in an improvement or weakness of the port's performance.

   For example, the total amount of tonnes handled in the port either discharged from or loaded onto all ships affects berth occupancy, the operations rate alongside a berth, gang productivity and consequently port performance. There is a causal relationship between port performance and these variables. Hence, the size of the effect varies with the size of the causal factor.

   For the revenue measures, total port revenues are determined by how long cargoes and ships remain in the port. In Damietta port, shippers, ship owners, cargo owners, brokers and the port's managers are willing to keep their cargoes for a shorter time to pay less tariffs and dues. The longer cargo or a ship remains in the port, the higher the cost and port revenue.

5. The system depends on the use of an adequate sample size to reduce the likelihood of sampling error. The number of samples used is 60 months from January 2004 to December 2008. This high sample size aimed to reduce errors. The fewer errors in the system, the greater the reliability.

For the OT step in DAPEMS, seven predictors were applied using regression analysis. These predictors have been considered by other researchers in the literature, separately, for different purposes:

1. UNCTAD (1976) used a NCS predictor to link port expenditures with port revenues.
2. UNCTAD (1976) applied a TTH predictor to determine port productivity, while Tongzon (1995) used it for evaluating overall port performance.
3. De and Ghosh (2003) applied a BO predictor to determine the operational performance at berth. Also, the BO predictor was recommended to be used as a measure of facility utilisation in relative to other factors (UNCTAD, 1985).
4. Chung (1993) used an LDR predictor for evaluating carriers' performance of bulk cargo.
5. UNCTAD (2004) used the ST predictor to get the ratio of inputs to outputs of port operations.
6. UNCTAD (1976) used TS as an indicator to calculate the service level provided in terms of the total time a ship stays in port. Also, it helped to calculate port revenues. Thus, it considered delay, pre-berthing and berthing time.
7. Chung (1993) highlighted the importance of the total time cargo stays in a port. But, he did not explain how it can be achieved.

It is important to highlight that these predictors in DAPEMS have been applied previously, but for different purposes of measurement and using different combinations as mentioned in the examples above.

7.2.4 Operational Reliability

Using relevant and a relative number of variables in the system helps to provide more information about the port's performance as follows:

1. The NCS predictor is significant in all models, with a positive relationship. It increases the degree of reliability as the predictor influences the volume of cargo that can be moved into the port. Increasing NCS in any port will increase the competitive position and will result in attracting more clients, such as shipping lines and freight forwarders (Slack, 1985; Cullinane et al., 2005).

2. The TTH predictor is only significant in dry and liquid bulk. This proves the reliability as bulk cargo depends on labour and capital productivity in a port rather than equipment efficiency and handling rates (Tongzon, 1995). Also, the predictor has positive trend with OT. Liquid and dry bulks require ships to be subject to safety inspections and tanks should be measured prior to any operations. Thus, the performance of operations relies on labour productivity. Increasing the volumes of loading or discharging requires maximising the labour productivity, and vice versa.

3. The reliability of the regression models exists also in the BO predictor. The predictor is significant only in general cargo and containers. According to Damietta port records, general cargo and container ships have the highest number of calls at the port. In 2010, 1283 general cargo ships and 1289 container ships called at the port, compared to 356 dry bulk ships and 245 liquid bulk ships called at the port.

4. For storage factors, previous models show that ST is significant in all types of cargo. One of the main port’s functions is to provide warehouses and storage yards for handling, dispatching, distribution and break-bulk. (UNCTAD, 2004). Therefore, ST is considered as one of the main performance indicators that influence a port’s performance.

It is obvious that ST applies in a positive direction in general cargo and dry bulk. ST is characterised as vertical storage in these types of cargo. However, ST is negative in liquid cargo as there is a maximum limit for storage tanks. Also, there are a maximum number of stacks for containers to avoid damage due to over stacking.

5. The handling rate is a major cost-item for sea-transportation. Hence, the emphasis is on reducing time in ports, and improving the efficiency of ship and cargo handling operations. LDR is only significant in containers where clearance time is zero, according to Damietta port records. This proves that the regression model is more reliable in predicating OT.

However, LDR has a positive relationship with OT at the container terminal. This means that increasing handling rates leads to an increase in total operation time. This refers to a specific problem at the container terminal in Damietta port. Interviews and observations showed that there are insufficient ship-to-shore cranes to handle the number of ships at berths. This explains why the port has started to establish a new container terminal and to invest in handling equipment. For other types of cargoes, LDR has a weak relationship with OT, because loading and discharging operations require specific precautions such as slowness in handling rates to avoid any leakage.

7.3. DAPEMS Applicability

Testing the applicability is useful, as it tests the generality. The higher the degree of generality, the more applicability the system has (Sekaran, 2003). Consequently, DAPEMS is more useful and has value to benefit the port managers as well as other ports when following and applying the same procedures and steps. Damietta port is a single case study in this research and it presents generality as the operating environment is similar but not exactly the same as other Egyptian ports.

However, generality is sometimes restricted when there are no similar situations and settings between ports. If this is the case, it does not necessarily decrease the usefulness and value of the system. Characteristics of DAPMES which can be generalised are listed below:

1. There are 15 commercial ports in Egypt, which are owned and operated by the government represented by the Maritime Transport Sector (MTS, 2011). These ports have adopted the same policies and strategies. In addition, they handle similar types of cargo in both imports and exports, but with different volumes. Consequently, the Egyptian ports have a fairly closed operating environment. Moreover, they apply the same pricing methods and the same tariffs (MOT, 2003).
2. All Egyptian ports have to fill and submit the same formal reports to the Ministry of Transport on a monthly basis. This means that all ports record the same types of data for the same variables. This means that there will be little difficulty in applying DAPMES to other ports, as the required types of monthly data will be available.
3. Applying DAPEMS in other ports will require access to new data, subsequently, the equations will be changed.
4. Selected variables in the system needed to be refreshed and reviewed periodically. This helps to refresh the system over the time and to take into consideration those variables that may change or a rise in the future and influencing port performance.
5. Generality can take place by applying the same system's steps and procedures.

7.4 DAPEMS Flexibility

In manufacturing and production industries, there is a wide range of literature that discusses flexibility. Some of these research focused on integerating flexibility measures into supply chain measurement systems (Neely et al., 1995; Beamon, 1999). However, Slack (1983) argued that flexibility is a measure of potential rather than performance. Hence, this part of the research will discuss the flexibility of DAPEMS as a feature (Chan, 2003), not as a measure.

Slack (1983) claimed that a system's output should have a flexibility characteristic as well as reliability. He discussed a design change flexibility is where it refers to a modification of an exisitng system design. Also, Slack argued that a system is more flexible if it is capable of exhibiting a wider range of behaviours, such as different output levels and different lead times. Time and cost are the main elements of system flexibility that influnce the quality of output. As a performance measurement system, flexibility is not a specific performance measure as it refers to the ability of the system to cope with environmental variations.

Slack (1983;1987) developed different frameworks and categories of flexibility measures to improve performance and to increase the competitiveness. Slack (1987) classified flexibility into two broad categories; resource flexibility and manufacturing flexibility. He argued that the resource flexibility contributes to the overall performance, while manufacturing performance focuses on individual resource flexibility rather than system flexibility. He also identified four sub-types of manufacturing flexibility; product, mix, volume and delivery. These types are similar in their ability to respond to any changing planned product quality levels.

Suarez et al. (1996) supported Slack's classification, and they proposed other types of flexibility measures, which are known as first-order flexibility types and lower-order flexibility types. They argued that first-order flexibility affects the competitive position of a firm, while the lower-order flexibility does not by itself directly affect the competitive position of the firm. However, they argued that the lower-order flexibility is essential to accomplish the overall system flexibility.

Vickery et al. (1999) argued that flexibility is the key dimension of supply chain performance and a system should be viewed as a value-adding system that has total system flexibility. They discussed four different types of flexibility as follows:

1. Product flexibility – it is related to cutomer satisfaction and marketing performance.
2. Volume flexibility – it is related to the production performance.
3. Access flexibility – it is related to the distribution coverage.
4. Responsivness flexibility – it is related to the overall firm's performance.

Each type has a different purpose, but all emphasise that flexibility is viewed as an adaptive issue to show the ability to respond to any change in the environment. However, they focused only on the strategic business units in firms with little regard for other levels, such as operational level.

Beamon and Chen (2001, p.3202) focused on the importance of system flexibility that is described as the ability to respond to fluctuations in proportion of demand in terms of speed and range. They recommended to calculate volume flexibility which measures the demand that can be met by the system in time units given product mix. Beamon (1999) argued that the problem in current measurment systems is the inflexibility that can be defined as late provision of valauble reports that would help to respond to any changes in the environment. She claimed that a measurement system has high flexibility in terms of how well the system will react to uncertianty. The main issue argued by her is that resources affect the system's output, and in turn, the system output will affect the system's flexibility.

Oke (2005) argued that there is a difference between system flexibility and system capability. The difference is based on which techniques are used to deliver it. He claimed that misunderstanding the difference between these terms made a confusion in the flexibility literature. Hence, he encompassed all flexibility types into three categories of system flexibility: generic factors, fundamental factors and shared factors. He argued that internal flexibility was the most important factor to define a system's flexibility in term of its design.

Kumar et al. (2008) argued that flexibility reflects the ability of a system to respond rapidly to changes that have occured inside and outside the system. They categorised the flexibility into five perspectives namely: sourcing flexibility, logistics flexibility, manufacturing flexibility, product development flexibility and information systems flexibility. They argued that flexibility has different sources which refer to the actions taken to meet the uncertainty, such as building long-term relationships with suppliers and contracting with third party logistics providers.

Roll (2010) examined the relationship between strategy, flexibility and performance in the supply chain context in the Netherlands and Belguim. A quantitative approach was applied uisng a quetionnaire survey to prove that a strategy has direct effects on flexibility, and in turn, flexibility affects performance. He concluded that new product flexibility, sourcing flexibility, product flexibility and delivery flexibility have weak relationships with the organisation’s performance in terms of net profit performance and sales growth performance. On the other hand, he proved that there is a positive relationship between new product flexibility and product flexibility and innovating strategy. However, his study was carried out in 2009 during a worldwide recession.

The operating environment in ports is dynamic, the demand on services provided in ports is uncertain and problems arise from the lack of operational measures of flexibility (Parker and Wirth, 1999). Integrating flexibility measures into DAEPEMS was considered in Chapter Six. The following part provides insights towards defining the measurement system's flexibility as a feature as follows:

1. Considering Slack's typology, volume flexibility exists in DAPEMS, which incorporates the response dimension of time to adjust the operations levels and the cost implications of changing volumes. The value of (OT) changes with any change in the port, such as a change in a number of calls, volumes and number of stacking containers in storage yards. And in turn, it affects the port's costs and revenues. In other words, the system is flexible, by Slack's definition, because it has the capability of volume flexibility.
2. OT, TS and CT show whether the port's performance is improving or weakening. They represent how long cargo is remaining in Damietta port. In the face of increasing demand in the port, the system has the ability to show any increase or a decrease in the traffic and volumes handled that influence the operating environment.
3. The measurement system provides information about the operating environment using time and revenue measures, which is considered as one of the flexibility tools to improve port performance through better planning and decreasing cost simultaneously.
4. Flexibility is important to respond to a changing environment. The time and revenue measures act as dimensions of a flexibility measure (Slack, 1983). Both dimensions provide DAPEMS with flexibility in terms of range and response. Range flexibility refers to the issue of how far the system can change in terms of uploading data, updating the regression models and substituting the values, and response flexibility focuses on the question of how rapidly and cheaply it can change (Slack, 1987).
5. Uncertainty of demand is a feature of most port operations and creating a responsive measurement system is one method of avoiding uncertainty. Establishing a system to deal with uncertainty increases the port's competitive status. DAPEMS is responsive in terms of providing the required information about the port's performance once data is available and uploaded. Beamon (1999) argued that late reports lead to inflexibility in systems.

Also, Neely (2005) argued that the implementation of recent measurement systems takes longer time and is not suitable for those organisations which have dynamic nature, like ports. He claimed that a system should have sufficient flexibility to cope with a dynamic environment through providing timely performance measurement.

6. The measurement system provides a number of outputs to meet the dynamic environment, as it provides a figure about port performance, such as OT, TS, revenues from OT. A diversity of outputs represent the performance of the system's behavior and it shows the the flexibility of the system (Slack, 1983).
7. The port managers can take actions according to the actual needs of current performance. The cost of action is determined by which actions have been taken in a timely and cost-effective manner. DAPEMS helps to understand operational situations.
8. Finally, DAPEMS has design change flexibility as it can be applied in other ports following the same steps and procedures, but with modifying the contents where data vary from one port to another (Slack, 1983).

7.5 The DAPEMS Feedback

Output is the main purpose of DAPMES, as from the port's point of view, the output is the system (Brown, 1996; Lynch and Cross, 1991). Neely (2004b) claimed that there is always a desire to quantify everything, but the focus in any performance measurement system should be on what managers need to measure rather than on what they can measure. The following part discusses the outputs from the system when it is applied to estimate the performance of Damietta port.

DAPEMS has been trialled by the operations manager at Damietta port for two months starting from March 2011 to April 2011. Two meetings with the operations manager took place and Table 7.3 shows the feedback received by him concerning the use of DAPEMS.

Table 7.3- DAPEMS Feedback

Positive Feedback	
1-	The port operations manager recognises the usefulness of using additional variables such as, operations time (OT).
2-	The usefulness of determining and understanding the relationship between variables and its significance.
3-	The correlation of relationship between predictor variables.
4-	Visibility of providing information of port revenue.
5-	Providing financial and non-financial information in one system.
Remarks and Suggestions	
1-	Human factor is not recorded by DAPEMS.
2-	DAPEMS considers only that each type of cargo has a one dedicated terminal, with no regard if there is more than one terminal for the same type of cargo.
3-	The system does not incorporate crisis management and risk tools.
4-	The system is only monitoring performance rather than providing solutions and decisions.
5-	The system excluded an in-port transportation variable.
6-	DAPEMS is not an electronic software with ease of use of figures and reports

The operations manager focused on the usefulness of integrating different measures (time and revenue measures) and predictor variables together in a system. He mentioned that variables are usually used separately for assessing a certain operation or a terminal.

In addition, the manager appreciated that not all variables were significant in all terminals and the significance of relationships and correlations between variables have been examined. This explains the real operating environment where every terminal has its own nature and specifications. Also, estimated monthly revenues for the port are useful, from his point of view, as information is not available from the government. Final positive feedback concerns the balance between the operational and financial information, where OT, TS and CT can be used for assessing the operational performance, while REVOT, REVTS and REVCT can be used for assessing financial performance.

However, negative feedback and suggestions were included. Firstly, the manager claimed that the system has not considered the human factor as the port relies on part-time workers. It is argued that it is very difficult to quantify the human factor in DAPEMS or in any other systems in Egypt as there is no accurate and available data about human factor in the port, nor in Egyptian governmental agencies. Unavailable data about the human and labour factors in ports was a problem in some studies carried out to measure port performance (Tongzon, 2001; Sharma and Yu, 2010).

Secondly, the manager mentioned that a new container terminal is under construction and it is proposed to operate in the next two years. He claimed that the system is designed to set only one terminal per type of cargo. However, it is argued that DAPEMS provides a possibility to measure a performance of two terminals for the same type of cargo, such as containers, following the same procedures with developing regression models.

Thirdly, the manager claimed that the system does not incorporate variables dealing with crisis management. However, it is argued that risks tools are different systems applied in organisations and companies as well as in ports. Hence, the researcher recommends combining DAPEMS with risk tools and crisis management as further possibilities for research. Also, the system can provide information and predict the performance in case of different disturbances. The performance assessment sheet has been developed with the co-operation of the operations manager.

Fourthly, the manager claimed that DAPEMS does not provide decisions and actions. However, the developed system is at the stage to identify measures and enhance the decision making process where full control is given to managers. Still, routine decisions can be automated for decision making. This is proposed as scope for further research.

Fifthly, the operations manager recommends incorporating in-port transportation variable in DAPEMS and he received a notice that the available data in Damietta port provide constant values for this variable. More actions toward quantifying this variable have been recommended by him to his supervisors and workers.

Finally, he claimed the possibility to make DAPEMS as electronic software to allow ease of use which provides accurate, timely and quick information, reports and figures. The research considered this claim as a recommendation as it requires technical specifications and experience. It appears as a suggestion to develop the functionality to allow the generation of reports and graphical representation.

7.6. DAPMES: Benefits and Limitations

The system can be functional for Damietta port. It can help the port to define and achieve their strategic objectives, align behaviour and attitudes and, ultimately, has a positive impact on port performance. However, it has also been criticized for some limitations. The system has the ability to combine measurements of time, revenue and flexibility in a single integrated system. When properly applied, it provides an early warning of performance problems. DAPEMS provides the following benefits:

1. It helps port managers to control and manage performance by providing various outputs that face all related aspects of the port operating environment.
2. There is no formal measurement system applied in Damietta port.
3. It covers both dimensions of performance: effectiveness and efficiency.
4. It meets the port's objectives in terms of how long cargo stays in ports. The system has a strategic focus.
5. The system focuses on measuring performance of port operations rather than terminal operations.
6. DAPEMS was developed using different measures, namely time, revenue and flexibility measures rather than relying solely on financial principles.
7. The system is applicable in practice as reported by the port operations manager.
8. It takes into consideration different terminals, including container, dry bulk, liquid bulk and general cargo terminals, rather than focusing only on containerised cargo.
9. It examines the relationship between the key performance variables.
10. It explains the cause and effect between key predictor variables.
11. It is easy to use by the port managers as the system is linked with easy designed Excel sheets to upload data in the future.
12. The system focuses on assessing future performance rather than historical performance.

However, DAPEMS has limitations as follows:

1. Currently, it is not applicable to other types of cargoes such as crude oil and natural gas, as these cargoes require dedicated measures.
2. The system has applicability in those ports that have fairly similar operating situations and similar pricing methods.
3. Statistically, some variables have been excluded as they have constant values such as the in-port transportation variable. These variables are important and should be considered in further research.
4. It is assumed that other port revenues have no great values such as tariffs received from towage and pilotage.

7.7. Chapter Summary

The characteristics of DAPEMS have been discussed including reliability, applicability and flexibility. The system reliability has been explained in terms of disturbance where a performance assessment sheet has been developed with the co-operation of the port manager to aid the system's reliability. Also, the system's reliability has been discussed with statistical, theoretical and operational dimensions. On the other hand, the system applicability has been found in following the same steps and procedures in other ports, with modification of content such as the regression models. As a feature, the system's flexibility has been illustrated in terms of how the system can cope with changes in the working environment. Finally, positive and negative feedback has been received as a result of testing DAPEMS for two months in Damietta port. Benefits and limitations of using the system have been summarised and discussed with the port operations manager.

Chapter Eight
Conclusions

8.1 Introduction

This chapter summarises the research findings, answers the research questions (Section 3.2), provides the results of the hypothesis testing and states the research's contributions to the development of knowledge. It concludes by acknowledging the more salient research limitations and by proposing areas for future study.

8.2 Conclusions

The growth of international trade between countries has expanded the derived demand for the maritime transport industry, especially ports. Port managers face difficulties in assessing their port's performance as they work in a dynamic environment. A wide range of performance measurement systems and frameworks have been developed for this purpose using a range of techniques including, econometric techniques, engineering techniques, operations research techniques, mathematical techniques and simulation. The conceptual framework from the literature review showed that most researchers applied techniques in the field of supply chain management to the port operations environment and its management.

However, it was found that the measurement systems currently applied in ports are limited in quantifying port performance. Current measures and KPIs focus on measuring efficiency and productivity issues rather than measuring performance (Pallis et al., 2011).

These measures aim to maximise productivity through maximising outputs or through minimising inputs for given outputs. Also, most measurement systems focus on measuring productivity for a certain terminal or terminals rather than for the port as a whole (Turner et al., 2004). These systems emphasise terminal operations rather than port operations (Chen, 1998; Musso et al., 1999).

Other measurement systems do not meet a strategic focus (Brooks, 2004; Robinson, 2006; Roso, 2008), and most systems rely heavily on cost measures and financial principles (Atkinson et al., 1997). In addition, measuring performance for containerised cargoes in container ports and container terminals is the objective in most recently developed systems (Stahlbook and Voss, 2008). This makes these systems inconsistent and unreliable because a port has many terminals and normally handles more than one type of cargo and measuring just one type of cargo is not considered sufficient to reflect a port's performance.

Contributing to the development of knowledge regarding this gap, this research was undertaken with the general aim of developing a more effective performance measurement system of operations at Damietta Port, Egypt. Specifically this research sought to answer the following question: "*how can current performance measurement systems be developed to measure the performance of ports?".* Thereby, the research was designed to answer the research question. It began by reviewing current supply chain performance measurement systems, designs and categories. This then led to a comprehensive discussion of these measurement systems and frameworks applied in ports and concluded with the weaknesses and limitations of current measurement systems applied in ports, particularly at Damietta port. It focused on the need to develop a reliable measurement approach.

A quantitative approach is a traditional approach towards assessing port performance (Marlow and Casaca, 2003). The development of the proposed system required evaluation of the effectiveness of the current measurement system at Damietta port. It was found that the current measurement approach applied in Damietta port was inadequate as it relied solely on the number of calling ships and total tonnes handled. The cooperation of the port director and managers ensured that the current system could be analysed in detail and that relevant variables related to port performance could be investigated.

Developing the proposed system, named DAPEMS, has taken place. The system was initially developed using time measures. It was assumed that reducing the total time cargo stays in the port could improve the port's performance. This could be achieved by controlling OT, TS and CT. Regression analyses were performed to calculate OT.

DAPEMS was then extended to integrate revenue and flexibility measures. The purpose was to provide greater visibility concerning port revenue for the port managers. A contingency plan was proposed for the top management to provide more flexibility in order to cope with rapid changes. DAPEMS' reliability, flexibility and applicability have then been explained. DAPEMS' reliability was explained in terms of disturbances, theoretical, statistical and operational issues. The system's flexibility was discussed to examine the capability of the system to deal with changes. For the system's applicability, the system was tested at Damietta port for two months and feedback has been discussed. Both positive and negative feedback was provided by the port operations manager.

8.3 Research Question and Hypothesis

The research findings can answer the question that current performance measurement systems can be developed to measure a port's performance by applying appropriate measures and reliable key performance variables that influence port performance and present the port's operations at all terminals for all types of cargoes handled. DAPEMS proved that it can help the port managers to assess and control the performance of their port.

Feedback received from the port's operations manager has proved the hypothesis which stated that *providing the port managers with a performance measurement system helps to monitor a port's performance*. The null hypothesis (H_N) is rejected as the research hypothesis is true. The port's operation manager indicated in his feedback that he would gain benefits from using DAPEMS in terms of getting detailed information for the port's operations, hence enabling him to assess performance, monitor monthly operations and acquire visibility concerning the port's revenue. The alternative hypothesis (H_A) is accepted.

8.4 Research Findings

This part discusses the results in relation to both existing knowledge and the research question. In the supply chain context, it was found that many earlier studies measured the organisation's performance using financial principles. Later, attention was shifted towards combining non-financial measures in parallel with financial measures.

Balances of set measures were recommended and accordingly new frameworks emerged such as the Balanced Scorecard and Performance Prism. Regarding the complexity and uncertainty of supply chains, recommendations were made to use multiple measures rather than a single measure because a business has many aspects that require different measures. Also, some studies focused on using measures that met the strategic objectives of organisations.

In port studies, the findings were diverse. Different approaches and frameworks were developed for assessing the performance of ports for different purposes and through using different techniques. Also, it was found that current measures applied in the port are based on financial principles following the traditional approach in the supply chain context. Little attention was given towards types of cargo other than containers, such as liquid bulk and dry bulk. Most studies focused on container ports or container terminals, while others concentrated on terminal productivity rather than port performance. It was found that no formal measurement system has been recommended in ports. A conceptual framework from the appropriate literature showed a need to contribute to the development of knowledge in terms of developing a port performance measurement system.

For the research strategy, a case study approach was applied to answer the research question. There were many findings after conducting the research. It was found that Damietta port had no formal measurement systems and the port managers relied on a limited number of variables. Also, the port records do not provide information about port revenue and the port managers focus on measuring the productivity of certain operations, separately.

Applying DAPEMS at Damietta port provided important findings. DAPEMS was useful in measuring the port's performance, from the port operations manager's perspective. Statistically, it was found that there are relationships between the key performance variables and OT. It was discovered that not all key variables were statistically significant in all types of cargoes. The actual operating environment at Damietta justified the significant and non-significant relationships between the predictors and OT. Also, the data showed constant values for two variables and consequently they have been excluded from the system, namely equipment and in-port transportation.

Positive feedback was provided by the port's operations manager concerning the integration of time, revenue and flexibility measures and the inclusion of more variables to provide further information about the port's operations. However, there were some limitations as the system is not applicable to other types of cargoes such as crude oil and natural gas, as these cargos require dedicated measures. The system has applicability in those ports that have a similar operating situation, similar pricing methods and infrastructure to Damietta Port. However, the system could be applied elsewhere following the same steps and procedures, but there is a need to modify the regression models and data.

8.5 Contributions to the Development of Knowledge

Findings in the literature showed that current systems of measuring port performance are inadequate and no model has been recommended as a standard system for port performance measurement. There is a gap in knowledge to find a reliable and relevant system that measures overall port performance. In this research, developing DAPEMS contributes to the development of knowledge through:

1. **Developing a port performance measurement system for Damietta Port**

Currently, Damietta port has no formal measurement system and the port managers rely on a limited number of measures to control and manage the performance. Each measure involves one or more KPIs for assessing the productivity of certain terminals and operations rather than measuring the port's performance.

As discussed earlier, the key performance indicators currently applied in Damietta Port are not effective, as they do not indicate the daily operations in the port, nor reflect the actual port performance. It is therefore quite evident that the port does not have an effective measurement system. The contribution was to develop a system that can be used in measuring Damietta's port performance. Positive feedback shows the usefulness of the system for the purpose of assessment. the system can provide the port managers with estimated number of operation time required for handling four types of cargo and estimated time required for ships waiting in port.

2. Consideration of relative and relevant key performance variables

As discussed in the literature, most current measurement systems are based on cargo handling as a key variable in port operations. Most studies have ignored key variables that influence a port's performance. Considering additional measures can provide more information regarding different operations and problems at ports, and consequently, help managers to select an appropriate way to deal with those problems. In Damietta port, managers rely currently on two measures: number of ships calling and total tonnes handled. This proved to be an inadequate measurement approach as it does not evaluate port performance. The contribution was to include in DAPEMS those performance variables which have been previously ignored by port managers. The purpose was to simulate the operating environment at the port and, in turn, to provide a reliable and effective system. Relevant and relative variables were selected such as time, revenue and flexibility measures.

3. Consideration of a ship turn-around time

DAPEMS takes ship turn-around time into account. The literature showed that current measurement systems exclude the total time a ship stays in port. It is obvious that this measure has previously been used for different purposes, such as ship output. The contribution was to examine the impacts of the ship turn-around time on how long cargo stays in port. It is argued 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. This argument has been discussed and approved by the port managers.

4. **Grouping key operations of Damietta port**

The literature showed that there are different operations in ports, such as physical operations, institutional operations and organisational operations. The contribution was to tailor the port's operations into five groups of operations. This helped to select the predictor variables that represent all five groups of operations. In the regression analyses, predictors have been selected from all groups to present both sides at the port: sea-side and land-side.

5. **Port terminals and types of cargoes handled**

Traditional measurement systems focus on containerised cargoes rather than other types of cargo. The contribution was to include other types of cargoes as well as containers. Dry bulk, liquid bulk, general cargoes and containers have been measured in DAPEMS. This enhanced the applicability and reliability of the system to present the port's performance. Also, DAPEMS has been designed to measure the productivity of various terminals. Current systems have been limited to containerised terminals, with no regard to other terminals in ports.

6. **Standing times consideration**

One of the most important contributions of this research is the incorporation of standing times. Non-operational times have been included to make the system display the port's performance accurately. Also, operational times, berthing times, un-berthing times and clearance time have been considered. Currently, DPA does not give attention towards standing time as the focus is always on how many tonnes are handled and how many calls arrive at the port.

7. **Integration of different performance measures**

DAPEMS involved more than one measurement category, because the port performance cannot be assessed using the value of one measure. The contribution was to integrate more measures in the system, including time, revenue and flexibility measures.

8. Allowing port managers to understand their performance

This research has contributed by presenting port managers with DAPEMS. It aimed to make port authorities and managers familiar with the system through a clear and detailed description. It aimed to make performance measures easy to be applied and understood. The system's steps represent the working environment and indicates a performance of operations and activities at existing terminals for the current types of cargo handled in the port. DAPEMS has been tested for two months at Damietta port and feedback has been received. The usefulness of applying the system has been recognised by the port operations manager.

9. Visibility, complexity and flexibility

The system has provided port managers with greater visibility about port revenue. Currently, the port has no formal record about revenue. Providing information about revenue assists the port managers in improving port facilities and services provided. On the other hand, the system can cope with complexity in the port by identifying problems and providing more information about complicated operations. This is due to using more variables in the system to define the scale rather than a limited number of variables currently applied at Damietta port. Also, the system has flexibility in terms of design change where contents can be modified when applying the system in other ports.

8.6 Research Limitations and Future Research

DAPEMS has been developed using measures in the following three categories: time, revenue and flexibility. It helps to understand and measure the performance of Damietta port and to increase the ability of the system to cope with environmental variations and complexity. However, some limitations exist as there are other means and considerations that can be used to measure, plan and improve the port's performance. Hence, the following limitations were found:

1. Two key primary variables have been excluded from the system because they have constant data: equipment availability and efficiency and in-port transportation. It is important to include them in future research under time measures as they have a great impact on port performance.

2. The system does not consider the organisational and administrative operations at Damietta port which have an effect on operations time (OT) and clearance time (CT).
3. The human factor was not considered in DAPEMS. Human resources assessment can be used in measuring the port's performance. In flexibility measures, human resources are a significant feature of a good master plan.
4. In addition to its value to Damietta port, DAPEMS could also be used by the Ministry of Transport and the broader stakeholders. The system could be used to evaluate the service provided by the port. This requires further development of the system to fit both: the port and the government. More measures are required to meet the government's needs, such as cost. This may encourage the government to provide reliable and accurate data about the port's costs.
5. DAPEMS helps to monitor the port performance for four types of cargoes: general cargo, dry bulk, liquid bulk and containers. It does not consider other types of cargoes such as crude oil and natural gas. This requires dedicated KPIs and measures in addition to those used in the system.
6. The system does not incorporate safety, cost, environment and security measures due to data being currently unavailable. Future research should take into consideration these measures as they influnce port performance.

The following areas of research require further investigation:

1. Other categories of measures can be included into the system, such as quality measures, assets management and cost measures. Including more measures will provide Damietta port management with the ability to change service levels rapidly, to take quick decisions to invest in new facilities and to respond to competitor ports. Also, considering more measures and variables will provide further information about the scale of settings. However, keeping any measurement systems as simple as possible was highly recommended by most researchers in the literature to avoid information overload.
2. Future research should investigate the incorporation of safety, cost, environmental and security measures into the system. Safety measures aims to reduce the number of accidents at ports and to provide workers protection.

These measures aim to reduce human failures such as carelessness, ignorance, inadequate skills and improper supervision. A variety of safety measures are widely used such as fencing of machinery, excessive weights, and fire precautions. Different cost measures are widely applied in ports, such as cargo handling activity, port infrastructure, facility utilisation, line-haul movement cost, connection cost, labour cost, and equipment and space cost. Environmental measures aim to use new technology to reduce environmental damage including air emission, dredging, and pollution. Security measures affect the traffic flow in seaports and aims to reduce attacks. Inspection for all types of cargo, exchanging information between port authorities and shipping lines and stevedoring companies, and labour time required for packing and unpacking are examples of security measures.

3. It is suggested for future studies to include comparative ports such as Alexandria port. This will help to test the system in other ports.
4. It is proposed to collect qualitative data, such as managers' behaviour and attitudes. This will help to understand how the managers at Damietta port deal with changes in demand, the decision-making process and their plans for future development. Currently, there are no qualitative data available due to confidentiality.
5. Regression analysis was applied to examine the relationships between key variables and operations time. It has been used to find the best models to represent total operations time (OT). Future research could be considered on using regression analysis on cost related variables. It can examine, for example, the relationship between total port revenues and OT, total port costs and OT, revenues and costs and OT, revenues and OT and costs and OT.
6. An information feedback system could be developed and then integrated with DAPEMS to provide a more proactive measurement and management system at Damietta port.
7. Based on the port operations manager’s recommendation, it is relevant to transfer the system into an electronic format using a dedicated software package for ease of use and to improve the system's response time.

8. Greater focus on port performance in developing countries, particularly the Middle East, is required as most studies were carried out for developed countries.

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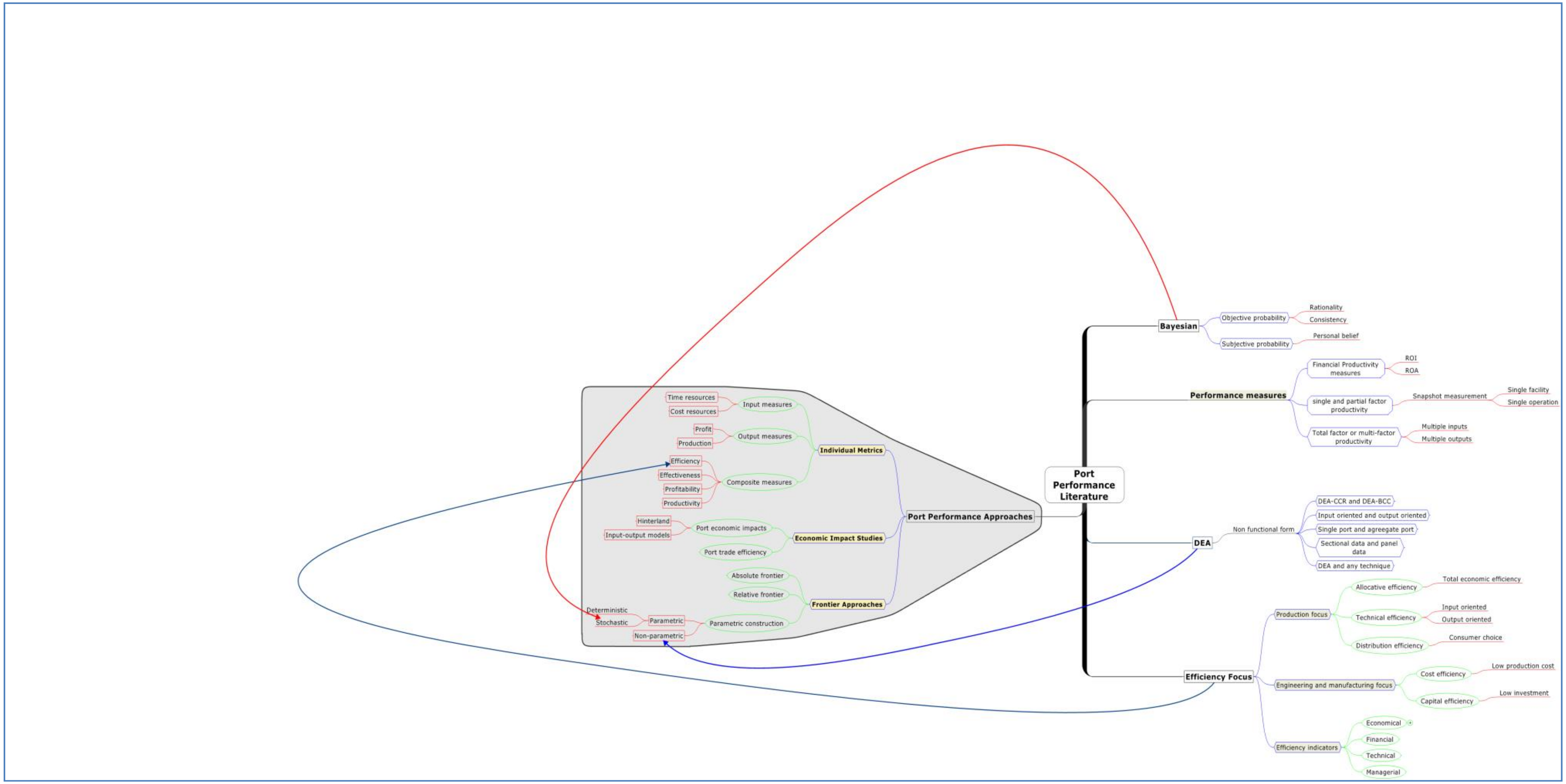
Appendix A

Port Performance Literature



Appendix B

Damietta Port Profile

10. Port ID Number (ISPS Code)	:	17373
11. Time Zone	:	+2 GMT
12. UNCTAD Code	:	EGDAM
13. Wave Code (VHF)	:	14-16
14. ISPS Code Source	http://www2.imo.org/ISPSCode/ISPSPortFacilities.aspx	
15. Long	:	31 o 48 / E
16. Lat	:	31 o 23 / N
17. Weather	:	Mild
18. Water Density	:	1.025 g/cm3
19. Raining Season	:	Autumn – winter
20. Tidal range and flow	:	0.61 m.
21. Total Area	:	11.8 km2.
22. Land Area	:	8.5 km2.
23. Water Area	:	3.3 km2.
24. Total Warehouses Area	:	0.1 km2 (142510 m2).
25. Total Yards Area	:	0.25 km2 (254231 m2).
26. Total Silos Area	:	0.09 km2 (98304 m2).
27. Maximum Port Length M	:	4 Km.
28. Maximum Port Breadth	:	3 km.
29. Maximum capacity (annually)	:	19.75 million tonnes
30. Maximum capacity (general cargo)	:	7 million tonnes
31. Maximum capacity (dry bulk)	:	7.5 million tonnes
32. Maximum capacity (containerised)	:	5.25 million tonnes
33. Maximum capacity (general cargo)	:	7 million tonnes
34. Maximum capacity (general cargo)	:	7 million tonnes
35. Max. Ship Size	:	14 m. draft-vessels
36. Unloading Containers Rate	:	2096 TEU/day .
37. Unloading Ships Rate	:	4523 ton/day
38. Working Hours Throughout	:	24 hours (in 3 shifts)

Location
Damietta Port is situated 10.5 km. west of the Nile river of Damietta branch westward Ras El-Bar, and 70 km. away from Port Said Port. The port installations extend on an area of 11.8 sq. Km.

Entrance Channel
11.4 km. long, 15 m. deep, and 300 m. wide gradually decreasing to reach 250 m. at the breakwater fringe, the approach channel is bordered by 18 nightly-lit buoys.

Breakwaters
The western breakwater is 1640 m. long with 140 m. land-based and 1500 m. sea-based area. The eastern breakwater is 750 m. long with 200 m. land-based and 550m sea-based area. Both breakwaters are made of stacked artificial piles topped with a concrete head.

Barge Channel
The barge channel consists of two sections; one is 1350 m. long connecting the barge dock to the sea and the other is 3750 m. connecting the basin to the Nile branch. The barge dock area is 250x250 m comprising a 250 m. long, 5m. deep quay.

Turning Dock
The turning dock diameter is 500 m. with 14.5 m. depth at the container berth, and 12 m. depth at the general cargo berth.

Navigation Channels
Entrance Channel 11.3 km. Length, 300 m. width, 15 m. depts. Barge Channel 4.5 km. length, 90 m. width, 5 m. Depth.

Pilotage
Pilotage is compulsory. Pilotage charges are payable in accordance with decree 60/1988 (concerning Egyptian vessels) and decree 73/1988 (concerning foreign vessels). Transhipment Containers are accorded 20-50% reduction according to decree 40/1990. Container carriers transiting the Egyptian ports are accorded 75%reduction.

Contacts
Damietta Port Authority. P.O. Box. 13 Damietta

Telephone	057/290940 - 290941 - 290942
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Telex	62204 DAMPA UN
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	damsite@emdb.gov.eg
	chairman-dpa@yahoo.com
Website	www.mts.gov.eg/ports/commercail/index.aspx

Port Security officer

Telephone	057/290940 - 290941 - 290942 - 290944 - 290954 - 290956
Fax	057/290930
Radio Terminal	Channel 14 for Naval Services
Radar Tower	External Tel: 290 964- Wireless channel 14.

Appendix C

A Supporting Letter

SUN, 01-JAN-00 0:12 EGYPT TLECOM******** **. P.01

MINISTRY OF TRANSPORT
DAMIETTA PORT AUTHORITY
Chairman Office

وزارة النقل
هيئة ميناء دمياط
مكتب رئيس مجلس الإدارة

D.P.A

Dear Nicoleta Tipi,
Head of Transport and Logistics Research Unit,
University Of Huddersfield,
Queensgate, Huddersfield, U.K.
HD 13 DH
Fax: 0044 1484 473019 or
0044 1484 473038

Dear Dr. N. Tipi

We are pleased to inform you , our confirmation and support to Mr. Khaled Gaber Abdalla El- Sakty in his PHD Thesis. He is supported in numerous ways, including resources that are available within the Port , that is fully accessible to him.

We appreciate that part of his studies and data are required. Time is available for him to carry out interviews, complete questionnaires, surveys , analysis information and statistics.

Chairman
Damietta Port Authority
R.ADM/ Hussein EL-Harmeil 17/10/7
Hussein El- Harmeil

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ص.ب ١٣ دمياط – جمهورية مصر العربية
ت : ٠٥٧ / ٢٩٠٩٤٤ – ٢٩٠٩٤١ – ٢٩٠٩٤٠
البريد الإلكتروني : Damsite@emdb.gov.eg
فاكس : ٠٥٧ / ٢٩٠٩٣٠

TOTAL P.01

Appendix D

Multiple Regression Analysis for General Cargo

Regression Analysis: OT versus NCS

```
The regression equation is
OT = 347 + 50.8 NCS


Predictor    Coef  SE Coef      T      P
Constant    347.3    190.2   1.83  0.073
NCS        50.811    2.540  20.00  0.000


S = 375.468   R-Sq = 87.3%   R-Sq(adj) = 87.1%
```

Regression Analysis: OT versus TTH

```
The regression equation is
OT = 1831 + 0.00567 TTH


Predictor        Coef     SE Coef     T      P
Constant       1831.4       296.1  6.19  0.000
TTH         0.0056670   0.0007240  7.83  0.000


S = 735.929   R-Sq = 51.4%   R-Sq(adj) = 50.5%
```

Regression Analysis: OT versus BO

```
The regression equation is
OT = 2962 + 13.3 BO


Predictor   Coef  SE Coef     T      P
Constant    2962     2842  1.04  0.302
BO         13.29    35.46  0.37  0.709


S = 1054.01   R-Sq = 0.2%   R-Sq(adj) = 0.0%
```

Regression Analysis: OT versus LDR

```
The regression equation is
OT = 4125 - 0.00478 LDR


Predictor        Coef   SE Coef      T      P
Constant       4125.1     174.2  23.68  0.000
LDR         -0.004783  0.005300  -0.90  0.371


S = 1047.95   R-Sq = 1.4%   R-Sq(adj) = 0.0%
```

Regression Analysis: OT versus ST

The regression equation is
OT = 3467 + 0.00727 ST

Predictor	Coef	SE Coef	T	P
Constant	3466.6	538.4	6.44	0.000
ST	0.007267	0.006770	1.07	0.288

S = 1044.95   R-Sq = 1.9%   R-Sq(adj) = 0.3%

Regression Analysis: OT versus NCS, ST

The regression equation is
OT = - 32 + 50.6 NCS + 0.00514 ST

Predictor	Coef	SE Coef	T	P
Constant	-31.6	253.4	-0.12	0.901
NCS	50.576	2.464	20.52	0.000
ST	0.005142	0.002360	2.18	0.033

S = 363.892   R-Sq = 88.3%   R-Sq(adj) = 87.9%

Regression Analysis: OT versus NCS, BO

The regression equation is
OT = - 715 + 50.8 NCS + 13.3 BO

Predictor	Coef	SE Coef	T	P
Constant	-715	1028	-0.70	0.490
NCS	50.811	2.538	20.02	0.000
BO	13.26	12.62	1.05	0.298

S = 375.128   R-Sq = 87.6%   R-Sq(adj) = 87.1%

Regression Analysis: OT versus NCS, LDR

The regression equation is
OT = 393 + 50.6 NCS - 0.00159 LDR

Predictor	Coef	SE Coef	T	P
Constant	393.1	198.5	1.98	0.052
NCS	50.632	2.556	19.81	0.000
LDR	-0.001587	0.001911	-0.83	0.410

S = 376.476   R-Sq = 87.5%   R-Sq(adj) = 87.1%

Regression Analysis: OT versus TTH, BO

The regression equation is
OT = 1480 + 0.00566 TTH + 4.4 BO

Predictor	Coef	SE Coef	T	P
Constant	1480	2010	0.74	0.465
TTH	0.0056611	0.0007309	7.74	0.000
BO	4.41	24.99	0.18	0.860

S = 742.154   R-Sq = 51.4%   R-Sq(adj) = 49.7%

Regression Analysis: OT versus TTH, ST

The regression equation is
OT = 1926 + 0.00572 TTH - 0.00149 ST

Predictor	Coef	SE Coef	T	P
Constant	1925.7	432.4	4.45	0.000
TTH	0.0057196	0.0007503	7.62	0.000
ST	-0.001490	0.004941	-0.30	0.764

S = 741.765   R-Sq = 51.4%   R-Sq(adj) = 49.7%

Regression Analysis: OT versus BO, LDR

The regression equation is
OT = 2869 + 15.7 BO - 0.00496 LDR

Predictor	Coef	SE Coef	T	P
Constant	2869	2847	1.01	0.318
BO	15.74	35.60	0.44	0.660
LDR	-0.004958	0.005352	-0.93	0.358

S = 1055.29   R-Sq = 1.7%   R-Sq(adj) = 0.0%

Regression Analysis: OT versus TTH, LDR

The regression equation is
OT = 1920 + 0.00564 TTH - 0.00383 LDR

Predictor	Coef	SE Coef	T	P
Constant	1920.1	308.2	6.23	0.000
TTH	0.0056424	0.0007241	7.79	0.000
LDR	-0.003825	0.003722	-1.03	0.308

S = 735.572   R-Sq = 52.3%   R-Sq(adj) = 50.6%

Regression Analysis: OT versus BO, ST

```
The regression equation is
OT = 3054 + 5.4 BO + 0.00704 ST

Predictor       Coef   SE Coef     T      P
Constant        3054      2843  1.07  0.287
BO              5.36     36.31  0.15  0.883
ST          0.007043  0.006994  1.01  0.318


S = 1053.88   R-Sq = 2.0%   R-Sq(adj) = 0.0%
```

Regression Analysis: OT versus LDR, ST

```
The regression equation is
OT = 3597 - 0.00426 LDR + 0.00672 ST

Predictor        Coef   SE Coef      T      P
Constant       3596.8     564.2   6.38  0.000
LDR         -0.004257  0.005328  -0.80  0.428
ST           0.006720  0.006826   0.98  0.329


S = 1048.23   R-Sq = 3.0%   R-Sq(adj) = 0.0%
```

Regression Analysis: OT versus NCS, TTH, BO

```
The regression equation is
OT = - 696 + 49.9 NCS + 0.000168 TTH + 13.0 BO

Predictor        Coef    SE Coef      T      P
Constant         -696       1038  -0.67  0.506
NCS            49.939      3.905  12.79  0.000
TTH         0.0001680  0.0005685   0.30  0.769
BO              13.00      12.75   1.02  0.312

S = 378.168   R-Sq = 87.6%   R-Sq(adj) = 86.9%
```

Regression Analysis: OT versus NCS, TTH, LDR

```
The regression equation is
OT = 392 + 49.4 NCS + 0.000231 TTH - 0.00162
LDR

Predictor        Coef    SE Coef      T      P
Constant        391.5      200.0   1.96  0.055
NCS            49.429      3.927  12.59  0.000
TTH         0.0002310  0.0005694   0.41  0.687
LDR         -0.001624   0.001927  -0.84  0.403

S = 379.266   R-Sq = 87.5%   R-Sq(adj) = 86.9%
```

Regression Analysis: OT versus NCS, TTH, ST

The regression equation is
OT = - 46 + 51.4 NCS - 0.000169 TTH + 0.00536 ST

Predictor	Coef	SE Coef	T	P
Constant	-46.0	260.2	-0.18	0.860
NCS	51.443	3.866	13.31	0.000
TTH	-0.0001690	0.0005776	-0.29	0.771
ST	0.005365	0.002497	2.15	0.036

S = 366.847   R-Sq = 88.3%   R-Sq(adj) = 87.7%

Regression Analysis: OT versus NCS, LDR, BO

The regression equation is
OT = - 733 + 50.6 NCS - 0.00175 LDR + 14.1 BO

Predictor	Coef	SE Coef	T	P
Constant	-733	1030	-0.71	0.479
NCS	50.614	2.551	19.84	0.000
LDR	-0.001746	0.001912	-0.91	0.365
BO	14.13	12.67	1.11	0.270

S = 375.677   R-Sq = 87.8%   R-Sq(adj) = 87.1%

Regression Analysis: OT versus NCS, ST, BO

The regression equation is
OT = - 636 + 50.6 NCS + 0.00481 ST + 7.8 BO

Predictor	Coef	SE Coef	T	P
Constant	-636	1003	-0.63	0.529
NCS	50.591	2.478	20.42	0.000
ST	0.004814	0.002430	1.98	0.053
BO	7.85	12.61	0.62	0.536

S = 365.863   R-Sq = 88.4%   R-Sq(adj) = 87.8%

Regression Analysis: OT versus TTH, BO, LDR

The regression equation is
OT = 1414 + 0.00563 TTH + 6.4 BO - 0.00390 LDR

Predictor	Coef	SE Coef	T	P
Constant	1414	2010	0.70	0.485
TTH	0.0056334	0.0007310	7.71	0.000
BO	6.38	25.05	0.25	0.800
LDR	-0.003898	0.003764	-1.04	0.305

S = 741.681   R-Sq = 52.3%   R-Sq(adj) = 49.8%

Regression Analysis: OT versus TTH, BO, ST

The regression equation is
OT = 1442 + 0.00572 TTH + 6.3 BO - 0.00175 ST

Predictor	Coef	SE Coef	T	P
Constant	1442	2029	0.71	0.480
TTH	0.0057205	0.0007566	7.56	0.000
BO	6.29	25.77	0.24	0.808
ST	-0.001754	0.005098	-0.34	0.732

S = 747.961   R-Sq = 51.5%   R-Sq(adj) = 48.9%

Regression Analysis: OT versus ST, LDR, BO

The regression equation is
OT = 2963 + 0.00636 ST - 0.00438 LDR + 8.3 BO

Predictor	Coef	SE Coef	T	P
Constant	2963	2854	1.04	0.304
ST	0.006358	0.007066	0.90	0.372
LDR	-0.004378	0.005399	-0.81	0.421
BO	8.30	36.60	0.23	0.821

S = 1057.06   R-Sq = 3.1%   R-Sq(adj) = 0.0%

Regression Analysis: OT versus ST, LDR, TTH

The regression equation is
OT = 2049 - 0.00199 ST - 0.00397 LDR + 0.00571 TTH

Predictor	Coef	SE Coef	T	P
Constant	2049.3	447.6	4.58	0.000
ST	-0.001987	0.004959	-0.40	0.690
LDR	-0.003969	0.003767	-1.05	0.297
TTH	0.0057117	0.0007497	7.62	0.000

S = 741.049   R-Sq = 52.4%   R-Sq(adj) = 49.8%

Regression Analysis: OT versus ST, LDR, NCS

The regression equation is
OT = 14 + 0.00499 ST - 0.00121 LDR + 50.4 NCS

Predictor	Coef	SE Coef	T	P
Constant	14.3	264.4	0.05	0.957
ST	0.004993	0.002383	2.09	0.041
LDR	-0.001208	0.001865	-0.65	0.520
NCS	50.446	2.485	20.30	0.000

S = 365.760   R-Sq = 88.4%   R-Sq(adj) = 87.8%

Regression Analysis: OT versus NCS, TTH, BO, LDR

The regression equation is
OT = - 712 + 49.6 NCS + 0.000190 TTH + 13.8 BO - 0.00177 LDR

Predictor	Coef	SE Coef	T	P
Constant	-712	1040	-0.68	0.496
NCS	49.625	3.926	12.64	0.000
TTH	0.0001900	0.0005698	0.33	0.740
BO	13.84	12.80	1.08	0.284
LDR	-0.001773	0.001929	-0.92	0.362

S = 378.694   R-Sq = 87.8%   R-Sq(adj) = 86.9%

Regression Analysis: OT versus NCS, TTH, BO, ST

The regression equation is
OT = - 652 + 51.5 NCS - 0.000171 TTH + 7.9 BO + 0.00504 ST

Predictor	Coef	SE Coef	T	P
Constant	-652	1013	-0.64	0.523
NCS	51.465	3.888	13.24	0.000
TTH	-0.0001705	0.0005808	-0.29	0.770
BO	7.86	12.71	0.62	0.539
ST	0.005038	0.002566	1.96	0.055

S = 368.885   R-Sq = 88.4%   R-Sq(adj) = 87.6%

Regression Analysis: OT versus NCS, TTH, LDR, ST

The regression equation is
OT = 1 + 51.2 NCS - 0.000140 TTH - 0.00117 LDR + 0.00518 ST

Predictor	Coef	SE Coef	T	P
Constant	1.0	272.3	0.00	0.997
NCS	51.168	3.913	13.08	0.000
TTH	-0.0001399	0.0005827	-0.24	0.811
LDR	-0.001171	0.001887	-0.62	0.537
ST	0.005181	0.002529	2.05	0.045

S = 368.877   R-Sq = 88.4%   R-Sq(adj) = 87.6%

Regression Analysis: OT versus NCS, BO, LDR, ST

The regression equation is
OT = - 653 + 50.4 NCS + 8.7 BO - 0.00134 LDR + 0.00461 ST

Predictor	Coef	SE Coef	T	P
Constant	-653	1008	-0.65	0.520
NCS	50.449	2.497	20.21	0.000
BO	8.74	12.73	0.69	0.495
LDR	-0.001335	0.001883	-0.71	0.481
ST	0.004612	0.002458	1.88	0.066

S = 367.499   R-Sq = 88.5%   R-Sq(adj) = 87.7%

Regression Analysis: OT versus TTH, BO, LDR, ST

```
The regression equation is
OT = 1358 + 0.00571 TTH + 9.0 BO - 0.00410 LDR
- 0.00238 ST

Predictor        Coef    SE Coef      T      P
Constant         1358       2028   0.67  0.506
TTH         0.0057127  0.0007556   7.56  0.000
BO               9.04      25.86   0.35  0.728
LDR         -0.004101   0.003815  -1.07  0.287
ST          -0.002383   0.005125  -0.47  0.644

S = 746.926   R-Sq = 52.5%   R-Sq(adj) = 49.0%
```

Regression Analysis: OT versus NCS, TTH, BO, LDR, ST

```
The regression equation is
OT = - 666 + 51.2 NCS - 0.000138 TTH + 8.7 BO
- 0.00130 LDR + 0.00480 ST

Predictor         Coef     SE Coef      T      P
Constant          -666        1018  -0.65  0.516
NCS             51.163       3.932  13.01  0.000
TTH         -0.0001383   0.0005855  -0.24  0.814
BO                8.72       12.84   0.68  0.500
LDR          -0.001299    0.001906  -0.68  0.498
ST            0.004799    0.002603   1.84  0.071

S = 370.695   R-Sq = 88.5%   R-Sq(adj) = 87.4%
```

Appendix E

Multiple Regression Analysis for Dry Bulk

Regression Analysis: OT versus NCS

```
The regression equation is
OT = - 34 + 56.8 NCS


Predictor    Coef  SE Coef      T      P
Constant    -34.4    108.8  -0.32  0.753
NCS        56.847    2.971  19.13  0.000


S = 191.888   R-Sq = 86.3%   R-Sq(adj) = 86.1%
```

Regression Analysis: OT versus TTH

```
The regression equation is
OT = 142 + 0.00528 TTH


Predictor        Coef    SE Coef     T      P
Constant        141.6      258.3  0.55  0.586
TTH         0.0052804  0.0007238  7.29  0.000


S = 374.721   R-Sq = 47.8%   R-Sq(adj) = 47.0%
```

Regression Analysis: OT versus BO

```
The regression equation is
OT = - 35 + 25.3 BO


Predictor   Coef  SE Coef      T      P
Constant     -35     1374  -0.03  0.980
BO         25.32    17.14   1.48  0.145


S = 509.390   R-Sq = 3.6%   R-Sq(adj) = 2.0%
```

Regression Analysis: OT versus LDR

```
The regression equation is
OT = 1775 + 0.0096 LDR


Predictor     Coef  SE Coef     T      P
Constant    1775.3    273.9  6.48  0.000
LDR        0.00955  0.01170  0.82  0.418


S = 515.936   R-Sq = 1.1%   R-Sq(adj) = 0.0%
```

Regression Analysis: OT versus ST

The regression equation is
OT = 3316 - 0.0114 ST

Predictor	Coef	SE Coef	T	P
Constant	3316.3	782.2	4.24	0.000
ST	-0.011445	0.006737	-1.70	0.095

S = 506.446   R-Sq = 4.7%   R-Sq(adj) = 3.1%

Regression Analysis: OT versus NCS, TTH

The regression equation is
OT = - 274 + 49.9 NCS + 0.00140 TTH

Predictor	Coef	SE Coef	T	P
Constant	-274.4	126.6	-2.17	0.034
NCS	49.862	3.540	14.09	0.000
TTH	0.0013955	0.0004416	3.16	0.003

S = 178.554   R-Sq = 88.4%   R-Sq(adj) = 88.0%

Regression Analysis: OT versus NCS, BO

The regression equation is
OT = - 704 + 56.3 NCS + 8.61 BO

Predictor	Coef	SE Coef	T	P
Constant	-704.1	515.2	-1.37	0.177
NCS	56.305	2.979	18.90	0.000
BO	8.605	6.473	1.33	0.189

S = 190.632   R-Sq = 86.7%   R-Sq(adj) = 86.3%

Regression Analysis: OT versus NCS, LDR

The regression equation is
OT = - 161 + 56.7 NCS + 0.00585 LDR

Predictor	Coef	SE Coef	T	P
Constant	-160.9	142.9	-1.13	0.265
NCS	56.668	2.953	19.19	0.000
LDR	0.005849	0.004324	1.35	0.181

S = 190.530   R-Sq = 86.7%   R-Sq(adj) = 86.3%

Regression Analysis: OT versus NCS, ST

The regression equation is
OT = - 624 + 58.5 NCS + 0.00457 ST

Predictor	Coef	SE Coef	T	P
Constant	-624.0	357.7	-1.74	0.086
NCS	58.542	3.082	19.00	0.000
ST	0.004574	0.002648	1.73	0.089

S = 188.688   R-Sq = 87.0%   R-Sq(adj) = 86.5%

Regression Analysis: OT versus TTH, BO

The regression equation is
OT = - 326 + 0.00521 TTH + 6.2 BO

Predictor	Coef	SE Coef	T	P
Constant	-326	1018	-0.32	0.750
TTH	0.0052055	0.0007456	6.98	0.000
BO	6.17	12.98	0.48	0.636

S = 377.247   R-Sq = 48.1%   R-Sq(adj) = 46.2%

Regression Analysis: OT versus TTH, LDR

The regression equation is
OT = 309 + 0.00568 TTH - 0.0136 LDR

Predictor	Coef	SE Coef	T	P
Constant	309.2	278.4	1.11	0.271
TTH	0.0056811	0.0007632	7.44	0.000
LDR	-0.013566	0.008958	-1.51	0.135

S = 370.612   R-Sq = 49.9%   R-Sq(adj) = 48.1%

Regression Analysis: OT versus TTH, ST

The regression equation is
OT = 40 + 0.00532 TTH + 0.00076 ST

Predictor	Coef	SE Coef	T	P
Constant	40.2	753.8	0.05	0.958
TTH	0.0053174	0.0007743	6.87	0.000
ST	0.000764	0.005333	0.14	0.887

S = 377.926   R-Sq = 47.9%   R-Sq(adj) = 46.0%

Regression Analysis: OT versus BO, LDR

The regression equation is
OT = - 316 + 25.9 BO + 0.0102 LDR

Predictor	Coef	SE Coef	T	P
Constant	-316	1412	-0.22	0.824
BO	25.92	17.18	1.51	0.137
LDR	0.01024	0.01158	0.88	0.380

S = 510.353   R-Sq = 4.9%   R-Sq(adj) = 1.6%

Regression Analysis: OT versus BO, ST

The regression equation is
OT = 1062 + 31.2 BO - 0.0136 ST

Predictor	Coef	SE Coef	T	P
Constant	1062	1444	0.74	0.465
BO	31.21	16.95	1.84	0.071
ST	-0.013563	0.006702	-2.02	0.048

S = 496.317   R-Sq = 10.1%   R-Sq(adj) = 6.9%

Regression Analysis: OT versus LDR, ST

The regression equation is
OT = 3099 + 0.0062 LDR - 0.0108 ST

Predictor	Coef	SE Coef	T	P
Constant	3098.8	888.7	3.49	0.001
LDR	0.00619	0.01175	0.53	0.600
ST	-0.010781	0.006896	-1.56	0.123

S = 509.629   R-Sq = 5.2%   R-Sq(adj) = 1.9%

Regression Analysis: OT versus NCS, TTH, BO

The regression equation is
OT = - 702 + 49.8 NCS + 0.00133 TTH + 5.64 BO

Predictor	Coef	SE Coef	T	P
Constant	-701.5	483.3	-1.45	0.152
NCS	49.842	3.545	14.06	0.000
TTH	0.0013287	0.0004482	2.96	0.004
BO	5.635	6.154	0.92	0.364

S = 178.808   R-Sq = 88.5%   R-Sq(adj) = 87.9%

Regression Analysis: OT versus NCS, TTH, LDR

The regression equation is
OT = - 285 + 50.0 NCS + 0.00136 TTH + 0.00074 LDR

Predictor	Coef	SE Coef	T	P
Constant	-284.8	142.1	-2.00	0.050
NCS	50.004	3.673	13.62	0.000
TTH	0.0013625	0.0004880	2.79	0.007
LDR	0.000740	0.004478	0.17	0.869

S = 180.098   R-Sq = 88.4%   R-Sq(adj) = 87.7%

Regression Analysis: OT versus NCS, TTH, ST

The regression equation is
OT = - 1110 + 51.2 NCS + 0.00159 TTH + 0.00622 ST

Predictor	Coef	SE Coef	T	P
Constant	-1110.3	348.6	-3.18	0.002
NCS	51.170	3.418	14.97	0.000
TTH	0.0015946	0.0004287	3.72	0.000
ST	0.006219	0.002433	2.56	0.013

S = 170.471   R-Sq = 89.6%   R-Sq(adj) = 89.0%

Regression Analysis: OT versus NCS, LDR, BO

The regression equation is
OT = - 869 + 56.1 NCS + 0.00613 LDR + 9.02 BO

Predictor	Coef	SE Coef	T	P
Constant	-869.2	523.6	-1.66	0.102
NCS	56.092	2.956	18.97	0.000
LDR	0.006125	0.004292	1.43	0.159
BO	9.025	6.422	1.41	0.165

S = 188.921   R-Sq = 87.2%   R-Sq(adj) = 86.5%

Regression Analysis: OT versus NCS, ST, BO

The regression equation is
OT = - 1044 + 57.9 NCS + 0.00397 ST + 6.41 BO

Predictor	Coef	SE Coef	T	P
Constant	-1044.4	561.1	-1.86	0.068
NCS	57.914	3.150	18.38	0.000
ST	0.003968	0.002722	1.46	0.150
BO	6.405	6.586	0.97	0.335

S = 188.777   R-Sq = 87.2%   R-Sq(adj) = 86.5%

Regression Analysis: OT versus BO, LDR, TTH

The regression equation is
OT = 13 + 3.9 BO - 0.0132 LDR + 0.00562 TTH

Predictor	Coef	SE Coef	T	P
Constant	13	1035	0.01	0.990
BO	3.86	12.96	0.30	0.767
LDR	-0.013234	0.009100	-1.45	0.151
TTH	0.0056245	0.0007926	7.10	0.000

S = 373.610   R-Sq = 49.9%   R-Sq(adj) = 47.3%

Regression Analysis: OT versus BO, ST, TTH

The regression equation is
OT = - 335 + 6.1 BO + 0.00011 ST + 0.00521 TTH

Predictor	Coef	SE Coef	T	P
Constant	-335	1129	-0.30	0.768
BO	6.10	13.58	0.45	0.655
ST	0.000107	0.005566	0.02	0.985
TTH	0.0052115	0.0008146	6.40	0.000

S = 380.599   R-Sq = 48.1%   R-Sq(adj) = 45.3%

Regression Analysis: OT versus BO, ST, LDR

The regression equation is
OT = 833 + 31.3 BO - 0.0129 ST + 0.0064 LDR

Predictor	Coef	SE Coef	T	P
Constant	833	1511	0.55	0.583
BO	31.29	17.05	1.83	0.072
ST	-0.012886	0.006854	-1.88	0.065
LDR	0.00636	0.01152	0.55	0.583

S = 499.369   R-Sq = 10.6%   R-Sq(adj) = 5.8%

Regression Analysis: OT versus TTH, ST, LDR

The regression equation is
OT = 287 + 0.00569 TTH + 0.00016 ST - 0.0135 LDR

Predictor	Coef	SE Coef	T	P
Constant	287.3	763.9	0.38	0.708
TTH	0.0056884	0.0008053	7.06	0.000
ST	0.000164	0.005291	0.03	0.975
LDR	-0.013545	0.009064	-1.49	0.141

S = 373.903   R-Sq = 49.9%   R-Sq(adj) = 47.2%

Regression Analysis: OT versus NCS, ST, LDR

The regression equation is
OT = - 889 + 58.6 NCS + 0.00539 ST + 0.00740 LDR

Predictor	Coef	SE Coef	T	P
Constant	-889.1	383.5	-2.32	0.024
NCS	58.619	3.030	19.35	0.000
ST	0.005389	0.002645	2.04	0.046
LDR	0.007400	0.004278	1.73	0.089

S = 185.473 R-Sq = 87.7% R-Sq(adj) = 87.0%

Regression Analysis: OT versus NCS, TTH, BO, LDR

The regression equation is
OT = - 736 + 50.1 NCS + 0.00127 TTH + 5.85 BO + 0.00127 LDR

Predictor	Coef	SE Coef	T	P
Constant	-735.8	502.4	-1.46	0.149
NCS	50.085	3.678	13.62	0.000
TTH	0.0012696	0.0004985	2.55	0.014
BO	5.854	6.254	0.94	0.353
LDR	0.001268	0.004519	0.28	0.780

S = 180.297 R-Sq = 88.6% R-Sq(adj) = 87.7%

Regression Analysis: OT versus NCS, TTH, BO, ST

The regression equation is
OT = - 1218 + 51.1 NCS + 0.00157 TTH + 1.76 BO + 0.00602 ST

Predictor	Coef	SE Coef	T	P
Constant	-1217.7	513.2	-2.37	0.021
NCS	51.123	3.450	14.82	0.000
TTH	0.0015675	0.0004425	3.54	0.001
BO	1.762	6.138	0.29	0.775
ST	0.006024	0.002545	2.37	0.021

S = 171.885 R-Sq = 89.6% R-Sq(adj) = 88.8%

Regression Analysis: OT versus NCS, TTH, LDR, ST

The regression equation is
OT = - 1157 + 51.6 NCS + 0.00151 TTH + 0.00202 LDR + 0.00635 ST

Predictor	Coef	SE Coef	T	P
Constant	-1156.5	364.6	-3.17	0.002
NCS	51.587	3.554	14.51	0.000
TTH	0.0015090	0.0004686	3.22	0.002
LDR	0.002020	0.004297	0.47	0.640
ST	0.006353	0.002466	2.58	0.013

S = 171.669 R-Sq = 89.6% R-Sq(adj) = 88.9%

Regression Analysis: OT versus NCS, BO, LDR, ST

The regression equation is
OT = - 1314 + 58.0 NCS + 6.46 BO + 0.00742 LDR + 0.00478 ST

Predictor	Coef	SE Coef	T	P
Constant	-1314.0	572.8	-2.29	0.026
NCS	57.985	3.095	18.73	0.000
BO	6.464	6.470	1.00	0.322
LDR	0.007423	0.004278	1.74	0.088
ST	0.004779	0.002715	1.76	0.084

S = 185.476   R-Sq = 87.9%   R-Sq(adj) = 87.0%

Regression Analysis: OT versus TTH, BO, LDR, ST

The regression equation is
OT = 35 + 0.00561 TTH + 4.0 BO - 0.0133 LDR - 0.00026 ST

Predictor	Coef	SE Coef	T	P
Constant	35	1147	0.03	0.976
TTH	0.0056107	0.0008530	6.58	0.000
BO	4.02	13.52	0.30	0.767
LDR	-0.013253	0.009191	-1.44	0.155
ST	-0.000256	0.005519	-0.05	0.963

S = 376.984   R-Sq = 49.9%   R-Sq(adj) = 46.3%

Regression Analysis: OT versus TTH, BO, LDR, ST, NCS

The regression equation is
OT = - 1286 + 0.00147 TTH + 2.06 BO + 0.00216 LDR + 0.00613 ST + 51.6 NCS

Predictor	Coef	SE Coef	T	P
Constant	-1285.5	534.5	-2.40	0.020
TTH	0.0014712	0.0004860	3.03	0.004
BO	2.064	6.210	0.33	0.741
LDR	0.002162	0.004354	0.50	0.622
ST	0.006134	0.002572	2.38	0.021
NCS	51.561	3.584	14.39	0.000

S = 173.075   R-Sq = 89.6%   R-Sq(adj) = 88.7%

Appendix F

Multiple Regression Analysis for Liquid Bulk

Regression Analysis: OT versus NCS

```
The regression equation is
OT = 4.4 + 55.7 NCS


Predictor     Coef  SE Coef      T      P
Constant      4.40    33.72   0.13  0.897
NCS         55.654    1.852  30.06  0.000


S = 85.0939   R-Sq = 94.0%   R-Sq(adj) = 93.9%
```

Regression Analysis: OT versus TTH

```
The regression equation is
OT = - 335 + 0.00377 TTH


Predictor       Coef   SE Coef      T      P
Constant      -335.4     496.0  -0.68  0.502
TTH         0.003769  0.001435   2.63  0.011


S = 327.539   R-Sq = 10.6%   R-Sq(adj) = 9.1%
```

Regression Analysis: OT versus BO

```
The regression equation is
OT = 54.0 + 7.11 BO


Predictor     Coef  SE Coef      T      P
Constant     54.04    55.48   0.97  0.334
BO          7.1053   0.4104  17.31  0.000


S = 139.499   R-Sq = 83.8%   R-Sq(adj) = 83.5%
```

Regression Analysis: OT versus LDR

```
The regression equation is
OT = 863 + 0.00248 LDR


Predictor       Coef   SE Coef     T      P
Constant       863.1     175.9  4.91  0.000
LDR         0.002485  0.004248  0.58  0.561


S = 345.450   R-Sq = 0.6%   R-Sq(adj) = 0.0%
```

Regression Analysis: OT versus ST

```
The regression equation is
OT = 2713 - 0.0456 ST


Predictor        Coef   SE Coef      T      P
Constant       2712.5     216.9  12.50  0.000
ST          -0.045550  0.005591  -8.15  0.000


S = 236.589   R-Sq = 53.4%   R-Sq(adj) = 52.6%
```

Regression Analysis: OT versus NCS, TTH

```
The regression equation is
OT = - 332 + 54.4 NCS + 0.00104 TTH

Predictor         Coef    SE Coef      T      P
Constant        -332.2      121.5  -2.73  0.008
NCS             54.366      1.803  30.16  0.000
TTH          0.0010418  0.0003630   2.87  0.006


S = 80.2361   R-Sq = 94.7%   R-Sq(adj) = 94.5%
```

Regression Analysis: OT versus NCS, BO

```
The regression equation is
OT = - 12.4 + 46.0 NCS + 1.44 BO

Predictor    Coef  SE Coef      T      P
Constant   -12.43    33.07  -0.38  0.708
NCS        45.953    4.335  10.60  0.000
BO         1.4379   0.5861   2.45  0.017


S = 81.6357   R-Sq = 94.5%   R-Sq(adj) = 94.4%
```

Regression Analysis: OT versus NCS, LDR

```
The regression equation is
OT = - 69.1 + 55.6 NCS + 0.00186 LDR

Predictor        Coef   SE Coef      T      P
Constant       -69.10     52.29  -1.32  0.192
NCS            55.589     1.816  30.61  0.000
LDR          0.001863  0.001027   1.81  0.075


S = 83.4598   R-Sq = 94.3%   R-Sq(adj) = 94.1%
```

Regression Analysis: OT versus NCS, ST

The regression equation is
OT = 190 + 53.2 NCS - 0.00371 ST

Predictor	Coef	SE Coef	T	P
Constant	189.7	148.6	1.28	0.207
NCS	53.178	2.671	19.91	0.000
ST	-0.003712	0.002901	-1.28	0.206

S = 84.6301   R-Sq = 94.1%   R-Sq(adj) = 93.9%

Regression Analysis: OT versus TTH, BO

The regression equation is
OT = - 726 + 0.00235 TTH + 6.89 BO

Predictor	Coef	SE Coef	T	P
Constant	-726.0	185.8	-3.91	0.000
TTH	0.0023462	0.0005395	4.35	0.000
BO	6.8868	0.3622	19.01	0.000

S = 121.935   R-Sq = 87.8%   R-Sq(adj) = 87.4%

Regression Analysis: OT versus TTH, LDR

The regression equation is
OT = - 384 + 0.00426 TTH - 0.00300 LDR

Predictor	Coef	SE Coef	T	P
Constant	-384.1	503.9	-0.76	0.449
TTH	0.004259	0.001623	2.62	0.011
LDR	-0.003000	0.004555	-0.66	0.513

S = 329.150   R-Sq = 11.3%   R-Sq(adj) = 8.2%

Regression Analysis: OT versus TTH, ST

The regression equation is
OT = 925 + 0.00602 TTH - 0.0530 ST

Predictor	Coef	SE Coef	T	P
Constant	924.9	259.2	3.57	0.001
TTH	0.0060210	0.0007198	8.36	0.000
ST	-0.052992	0.003882	-13.65	0.000

S = 159.905   R-Sq = 79.1%   R-Sq(adj) = 78.3%

Regression Analysis: OT versus BO, LDR

```
The regression equation is
OT = - 208 + 7.27 BO + 0.00600 LDR

Predictor       Coef   SE Coef      T      P
Constant     -207.56     83.95  -2.47  0.016
BO            7.2714    0.3709  19.61  0.000
LDR         0.006001  0.001550   3.87  0.000


S = 125.219   R-Sq = 87.2%   R-Sq(adj) = 86.7%
```

Regression Analysis: OT versus BO, ST

```
The regression equation is
OT = - 368 + 7.96 BO + 0.00815 ST

Predictor       Coef   SE Coef      T      P
Constant      -367.9     317.3  -1.16  0.251
BO            7.9574    0.7512  10.59  0.000
ST          0.008147  0.006034   1.35  0.182


S = 138.520   R-Sq = 84.3%   R-Sq(adj) = 83.7%
```

Regression Analysis: OT versus LDR, ST

```
The regression equation is
OT = 2519 + 0.00834 LDR - 0.0492 ST

Predictor        Coef   SE Coef      T      P
Constant       2519.2     213.7  11.79  0.000
LDR          0.008341  0.002805   2.97  0.004
ST          -0.049216  0.005390  -9.13  0.000


S = 222.051   R-Sq = 59.6%   R-Sq(adj) = 58.2%
```

Regression Analysis: OT versus NCS, TTH, BO

```
The regression equation is
OT = - 441 + 41.2 NCS + 0.00131 TTH + 1.90 BO

Predictor        Coef    SE Coef      T      P
Constant       -440.8      115.1  -3.83  0.000
NCS            41.207      4.079  10.10  0.000
TTH         0.0013091  0.0003399   3.85  0.000
BO             1.9013     0.5394   3.53  0.001

S = 73.2313   R-Sq = 95.7%   R-Sq(adj) = 95.5%
```

Regression Analysis: OT versus NCS, TTH, LDR

The regression equation is
OT = - 321 + 54.5 NCS + 0.000923 TTH + 0.00069 LDR

Predictor	Coef	SE Coef	T	P
Constant	-321.0	123.5	-2.60	0.012
NCS	54.488	1.824	29.88	0.000
TTH	0.0009235	0.0004132	2.23	0.029
LDR	0.000686	0.001123	0.61	0.544

S = 80.6809   R-Sq = 94.8%   R-Sq(adj) = 94.5%

Regression Analysis: OT versus NCS, TTH, ST

The regression equation is
OT = - 6 + 43.8 NCS + 0.00215 TTH - 0.0137 ST

Predictor	Coef	SE Coef	T	P
Constant	-6.4	126.5	-0.05	0.960
NCS	43.837	2.775	15.80	0.000
TTH	0.0021531	0.0003957	5.44	0.000
ST	-0.013722	0.002998	-4.58	0.000

S = 69.0556   R-Sq = 96.2%   R-Sq(adj) = 96.0%

Regression Analysis: OT versus NCS, BO, LDR

The regression equation is
OT = - 137 + 42.0 NCS + 2.01 BO + 0.00299 LDR

Predictor	Coef	SE Coef	T	P
Constant	-136.86	51.75	-2.64	0.011
NCS	42.011	4.267	9.85	0.000
BO	2.0067	0.5807	3.46	0.001
LDR	0.0029852	0.0009947	3.00	0.004

S = 76.4436   R-Sq = 95.3%   R-Sq(adj) = 95.0%

Regression Analysis: OT versus NCS, BO, ST

The regression equation is
OT = - 68 + 45.7 NCS + 1.58 BO + 0.00108 ST

Predictor	Coef	SE Coef	T	P
Constant	-68.0	190.8	-0.36	0.723
NCS	45.705	4.450	10.27	0.000
BO	1.5814	0.7646	2.07	0.043
ST	0.001079	0.003651	0.30	0.769

S = 82.2971   R-Sq = 94.6%   R-Sq(adj) = 94.3%

Regression Analysis: OT versus TTH, BO, LDR

The regression equation is
OT = - 675 + 0.00171 TTH + 7.05 BO + 0.00369 LDR

Predictor	Coef	SE Coef	T	P
Constant	-675.2	181.2	-3.73	0.000
TTH	0.0017093	0.0005960	2.87	0.006
BO	7.0483	0.3579	19.69	0.000
LDR	0.003692	0.001668	2.21	0.031

S = 117.964   R-Sq = 88.8%   R-Sq(adj) = 88.2%

Regression Analysis: OT versus NCS, TTH, BO, ST

The regression equation is
OT = - 107 + 41.1 NCS + 0.00204 TTH + 0.680 BO - 0.0111 ST

Predictor	Coef	SE Coef	T	P
Constant	-106.8	160.2	-0.67	0.508
NCS	41.118	3.846	10.69	0.000
TTH	0.0020387	0.0004111	4.96	0.000
BO	0.6803	0.6666	1.02	0.312
ST	-0.011129	0.003929	-2.83	0.006

S = 69.0301   R-Sq = 96.2%   R-Sq(adj) = 96.0%

Regression Analysis: OT versus TTH, BO, ST

The regression equation is
OT = - 381 + 0.00310 TTH + 5.62 BO - 0.0115 ST

Predictor	Coef	SE Coef	T	P
Constant	-381.2	275.0	-1.39	0.171
TTH	0.0030959	0.0006939	4.46	0.000
BO	5.6174	0.8360	6.72	0.000
ST	-0.011470	0.006832	-1.68	0.099

S = 120.035   R-Sq = 88.4%   R-Sq(adj) = 87.8%

Regression Analysis: OT versus LDR, BO, ST

The regression equation is
OT = - 363 + 0.00578 LDR + 7.60 BO + 0.00318 ST

Predictor	Coef	SE Coef	T	P
Constant	-362.8	288.6	-1.26	0.214
LDR	0.005780	0.001608	3.59	0.001
BO	7.5982	0.6905	11.00	0.000
ST	0.003184	0.005659	0.56	0.576

S = 125.977   R-Sq = 87.2%   R-Sq(adj) = 86.6%

Regression Analysis: OT versus LDR, TTH, ST

The regression equation is
OT = 955 + 0.00134 LDR + 0.00582 TTH - 0.0533 ST

Predictor	Coef	SE Coef	T	P
Constant	954.7	265.4	3.60	0.001
LDR	0.001343	0.002249	0.60	0.553
TTH	0.0058158	0.0008013	7.26	0.000
ST	-0.053328	0.003944	-13.52	0.000

S = 160.815   R-Sq = 79.2%   R-Sq(adj) = 78.1%

Regression Analysis: OT versus LDR, NCS, ST

The regression equation is
OT = 215 + 0.00266 LDR + 51.3 NCS - 0.00633 ST

Predictor	Coef	SE Coef	T	P
Constant	215.2	142.5	1.51	0.137
LDR	0.002664	0.001064	2.50	0.015
NCS	51.339	2.659	19.30	0.000
ST	-0.006330	0.002966	-2.13	0.037

S = 80.9737   R-Sq = 94.7%   R-Sq(adj) = 94.4%

Regression Analysis: OT versus NCS, TTH, BO, LDR

The regression equation is
OT = - 426 + 39.9 NCS + 0.00104 TTH + 2.14 BO + 0.00173 LDR

Predictor	Coef	SE Coef	T	P
Constant	-426.2	113.7	-3.75	0.000
NCS	39.885	4.095	9.74	0.000
TTH	0.0010444	0.0003706	2.82	0.007
BO	2.1367	0.5496	3.89	0.000
LDR	0.001727	0.001039	1.66	0.102

S = 72.1053   R-Sq = 95.9%   R-Sq(adj) = 95.6%

Regression Analysis: OT versus NCS, TTH, LDR, ST

The regression equation is
OT = 19 + 43.8 NCS + 0.00199 TTH + 0.00111 LDR - 0.0140 ST

Predictor	Coef	SE Coef	T	P
Constant	19.2	128.1	0.15	0.882
NCS	43.788	2.767	15.82	0.000
TTH	0.0019884	0.0004198	4.74	0.000
LDR	0.0011060	0.0009630	1.15	0.256
ST	-0.014044	0.003003	-4.68	0.000

S = 68.8598   R-Sq = 96.3%   R-Sq(adj) = 96.0%

Regression Analysis: OT versus NCS, BO, LDR, ST

```
The regression equation is
OT = - 89 + 42.2 NCS + 1.89 BO + 0.00304 LDR -
0.00099 ST

Predictor        Coef   SE Coef      T      P
Constant        -88.6     178.8  -0.50  0.622
NCS            42.161     4.335   9.73  0.000
BO             1.8867    0.7234   2.61  0.012
LDR          0.003043  0.001024   2.97  0.004
ST          -0.000985  0.003489  -0.28  0.779

S = 77.0796   R-Sq = 95.3%   R-Sq(adj) = 95.0%
```

Regression Analysis: OT versus TTH, BO, LDR, ST

```
The regression equation is
OT = - 375 + 0.00241 TTH + 5.92 BO + 0.00344
LDR - 0.0101 ST

Predictor        Coef    SE Coef      T      P
Constant       -375.2      267.2  -1.40  0.166
TTH         0.0024119  0.0007502   3.21  0.002
BO             5.9204     0.8252   7.17  0.000
LDR          0.003443   0.001657   2.08  0.042
ST          -0.010093   0.006671  -1.51  0.136

S = 116.630   R-Sq = 89.3%   R-Sq(adj) = 88.5%
```

Regression Analysis: OT versus NCS, TTH, BO, LDR, ST

```
The regression equation is
TOT = - 112 + 40.0 NCS + 0.00178 TTH + 0.942
BO + 0.00146 LDR - 0.0106 ST

Predictor        Coef    SE Coef      T      P
Constant       -111.7      158.6  -0.70  0.484
NCS            40.005      3.879  10.31  0.000
TTH         0.0017772  0.0004436   4.01  0.000
BO             0.9425     0.6830   1.38  0.173
LDR         0.0014608  0.0009892   1.48  0.146
ST          -0.010554   0.003907  -2.70  0.009

S = 68.3008   R-Sq = 96.4%   R-Sq(adj) = 96.0%
```

Appendix G

Multiple Regression Analysis for Containers

Regression Analysis: OT versus NCS

```
The regression equation is
TOT = - 116 + 16.6 NCS


Predictor    Coef  SE Coef      T      P
Constant   -115.9    157.5  -0.74  0.465
NCS        16.613    1.272  13.06  0.000


S = 142.049   R-Sq = 74.6%   R-Sq(adj) = 74.2%
```

Regression Analysis: OT versus TTH

```
The regression equation is
TOT = 1118 + 0.000816 TTH


Predictor        Coef    SE Coef     T      P
Constant       1117.9      185.4  6.03  0.000
TTH         0.0008161  0.0001844  4.43  0.000


S = 243.765   R-Sq = 25.2%   R-Sq(adj) = 24.0%
```

Regression Analysis: OT versus BO

```
The regression equation is
TOT = - 1115 + 38.0 BO


Predictor     Coef  SE Coef      T      P
Constant   -1115.2    691.6  -1.61  0.112
BO          37.978    8.626   4.40  0.000


S = 244.088   R-Sq = 25.0%   R-Sq(adj) = 23.8%
```

Regression Analysis: OT versus LDR

```
The regression equation is
TOT = 484 + 0.383 LDR


Predictor     Coef  SE Coef     T      P
Constant     484.5    225.2  2.15  0.036
LDR        0.38275  0.05931  6.45  0.000


S = 215.100   R-Sq = 41.8%   R-Sq(adj) = 40.8%
```

Regression Analysis: OT versus ST

```
The regression equation is
TOT = 1873 + 0.00084 ST


Predictor       Coef   SE Coef      T      P
Constant      1872.6     152.4  12.29  0.000
ST          0.000841  0.002306   0.36  0.717


S = 281.616   R-Sq = 0.2%   R-Sq(adj) = 0.0%
```

Regression Analysis: OT versus NCS, TTH

```
The regression equation is
TOT = - 109 + 17.2 NCS - 0.000075 TTH

Predictor         Coef    SE Coef      T      P
Constant        -108.7      159.0  -0.68  0.497
NCS             17.159      1.623  10.57  0.000
TTH         -0.0000750  0.0001371  -0.55  0.586


S = 142.915   R-Sq = 74.7%   R-Sq(adj) = 73.9%
```

Regression Analysis: OT versus NCS, BO

```
The regression equation is
TOT = - 855 + 15.4 NCS + 11.2 BO

Predictor    Coef  SE Coef      T      P
Constant   -855.3    392.6  -2.18  0.034
NCS        15.362    1.381  11.12  0.000
BO         11.151    5.451   2.05  0.045


S = 138.302   R-Sq = 76.4%   R-Sq(adj) = 75.5%
```

Regression Analysis: OT versus NCS, LDR

```
The regression equation is
TOT = - 197 + 15.0 NCS + 0.0738 LDR

Predictor     Coef  SE Coef      T      P
Constant    -196.9    166.4  -1.18  0.241
NCS         15.010    1.697   8.85  0.000
LDR        0.07379  0.05223   1.41  0.163


S = 140.845   R-Sq = 75.5%   R-Sq(adj) = 74.6%
```

Regression Analysis: OT versus NCS, ST

The regression equation is
TOT = - 24 + 17.3 NCS - 0.00272 ST

Predictor	Coef	SE Coef	T	P
Constant	-23.8	156.5	-0.15	0.880
NCS	17.285	1.257	13.75	0.000
ST	-0.002722	0.001149	-2.37	0.021

S = 136.716   R-Sq = 76.9%   R-Sq(adj) = 76.1%

Regression Analysis: OT versus TTH, BO

The regression equation is
TOT = - 889 + 0.000599 TTH + 27.7 BO

Predictor	Coef	SE Coef	T	P
Constant	-889.3	644.2	-1.38	0.173
TTH	0.0005990	0.0001837	3.26	0.002
BO	27.747	8.583	3.23	0.002

S = 226.041   R-Sq = 36.8%   R-Sq(adj) = 34.6%

Regression Analysis: OT versus TTH, LDR

The regression equation is
TOT = 454 + 0.000252 TTH + 0.325 LDR

Predictor	Coef	SE Coef	T	P
Constant	453.9	225.8	2.01	0.049
TTH	0.0002523	0.0002094	1.20	0.233
LDR	0.32450	0.07634	4.25	0.000

S = 214.268   R-Sq = 43.2%   R-Sq(adj) = 41.2%

Regression Analysis: OT versus TTH, ST

The regression equation is
TOT = 1148 + 0.00137 TTH - 0.00899 ST

Predictor	Coef	SE Coef	T	P
Constant	1148.3	168.0	6.84	0.000
TTH	0.0013673	0.0002231	6.13	0.000
ST	-0.008985	0.002415	-3.72	0.000

S = 220.568   R-Sq = 39.9%   R-Sq(adj) = 37.7%

Regression Analysis: OT versus BO, LDR

The regression equation is
TOT = - 997 + 21.7 BO + 0.314 LDR

Predictor	Coef	SE Coef	T	P
Constant	-997.3	577.9	-1.73	0.090
BO	21.717	7.872	2.76	0.008
LDR	0.31437	0.06142	5.12	0.000

S = 203.798   R-Sq = 48.7%   R-Sq(adj) = 46.8%

Regression Analysis: OT versus BO, ST

The regression equation is
TOT = - 1110 + 38.4 BO - 0.00056 ST

Predictor	Coef	SE Coef	T	P
Constant	-1109.7	697.5	-1.59	0.117
BO	38.355	8.805	4.36	0.000
ST	-0.000555	0.002040	-0.27	0.786

S = 246.060   R-Sq = 25.1%   R-Sq(adj) = 22.5%

Regression Analysis: OT versus LDR, ST

The regression equation is
TOT = 517 + 0.386 LDR - 0.00069 ST

Predictor	Coef	SE Coef	T	P
Constant	517.1	242.1	2.14	0.037
LDR	0.38586	0.06029	6.40	0.000
ST	-0.000690	0.001790	-0.39	0.701

S = 216.697   R-Sq = 41.9%   R-Sq(adj) = 39.9%

Regression Analysis: OT versus TTH, NCS, BO

The regression equation is
TOT = - 885 - 0.000113 TTH + 16.1 NCS + 11.8 BO

Predictor	Coef	SE Coef	T	P
Constant	-885.1	395.2	-2.24	0.029
TTH	-0.0001129	0.0001342	-0.84	0.404
NCS	16.115	1.649	9.77	0.000
BO	11.764	5.513	2.13	0.037

S = 138.658   R-Sq = 76.6%   R-Sq(adj) = 75.4%

Regression Analysis: OT versus TTH, NCS, LDR

The regression equation is
TOT = - 208 - 0.000172 TTH + 15.7 NCS + 0.0990 LDR

Predictor	Coef	SE Coef	T	P
Constant	-208.1	166.0	-1.25	0.215
TTH	-0.0001720	0.0001455	-1.18	0.242
NCS	15.716	1.793	8.77	0.000
LDR	0.09898	0.05624	1.76	0.084

S = 140.355   R-Sq = 76.1%   R-Sq(adj) = 74.8%

Regression Analysis: OT versus TTH, NCS, ST

The regression equation is
TOT = 4 + 0.000258 TTH + 15.8 NCS - 0.00427 ST

Predictor	Coef	SE Coef	T	P
Constant	3.8	156.2	0.02	0.981
TTH	0.0002581	0.0001780	1.45	0.153
NCS	15.787	1.618	9.76	0.000
ST	-0.004268	0.001560	-2.74	0.008

S = 135.413   R-Sq = 77.7%   R-Sq(adj) = 76.5%

Regression Analysis: OT versus NCS, LDR, BO

The regression equation is
TOT = - 853 + 14.2 NCS + 0.0584 LDR + 10.1 BO

Predictor	Coef	SE Coef	T	P
Constant	-852.9	391.7	-2.18	0.034
NCS	14.207	1.718	8.27	0.000
LDR	0.05838	0.05184	1.13	0.265
BO	10.150	5.510	1.84	0.071

S = 137.978   R-Sq = 76.9%   R-Sq(adj) = 75.6%

Regression Analysis: OT versus NCS, BO, ST

The regression equation is
TOT = - 816 + 16.0 NCS + 12.0 BO - 0.00289 ST

Predictor	Coef	SE Coef	T	P
Constant	-816.4	374.3	-2.18	0.033
NCS	15.976	1.337	11.95	0.000
BO	12.041	5.205	2.31	0.024
ST	-0.002891	0.001110	-2.60	0.012

S = 131.777   R-Sq = 78.9%   R-Sq(adj) = 77.8%

Regression Analysis: OT versus TTH, BO, LDR

```
The regression equation is
TOT = - 946 + 0.000171 TTH + 20.7 BO + 0.278
LDR

Predictor        Coef    SE Coef      T      P
Constant       -946.3      582.5  -1.62  0.110
TTH         0.0001711  0.0002022   0.85  0.401
BO             20.667      7.989   2.59  0.012
LDR           0.27819    0.07496   3.71  0.000
S = 204.308   R-Sq = 49.3%   R-Sq(adj) = 46.6%
```

Regression Analysis: OT versus TTH, BO, ST

```
The regression equation is
TOT = - 611 + 0.00112 TTH + 24.3 BO - 0.00812
ST
Predictor        Coef    SE Coef      T      P
Constant       -611.2      591.5  -1.03  0.306
TTH         0.0011244  0.0002225   5.05  0.000
BO             24.283      7.871   3.09  0.003
ST          -0.008124   0.002270  -3.58  0.001

S = 205.732   R-Sq = 48.6%   R-Sq(adj) = 45.8%
```

Regression Analysis: OT versus BO, LDR, ST

```
The regression equation is
TOT = - 984 + 22.4 BO + 0.318 LDR - 0.00124 ST

Predictor        Coef   SE Coef      T      P
Constant       -983.8     580.6  -1.69  0.096
BO             22.375     7.956   2.81  0.007
LDR           0.31786   0.06186   5.14  0.000
ST          -0.001235  0.001702  -0.73  0.471

S = 204.650   R-Sq = 49.1%   R-Sq(adj) = 46.4%
```

Regression Analysis: OT versus TTH, LDR, ST

```
The regression equation is
TOT = 649 + 0.000731 TTH + 0.238 LDR - 0.00536
ST
Predictor        Coef    SE Coef      T      P
Constant        648.9      239.7   2.71  0.009
TTH         0.0007312  0.0003111   2.35  0.022
LDR           0.23808    0.08557   2.78  0.007
ST          -0.005359   0.002630  -2.04  0.046

S = 208.578   R-Sq = 47.2%   R-Sq(adj) = 44.3%
```

Regression Analysis: OT versus NCS, LDR, ST

The regression equation is
TOT = - 103 + 15.7 NCS + 0.0710 LDR - 0.00268 ST

Predictor	Coef	SE Coef	T	P
Constant	-103.0	165.0	-0.62	0.535
NCS	15.733	1.661	9.47	0.000
LDR	0.07099	0.05027	1.41	0.163
ST	-0.002684	0.001139	-2.36	0.022

S = 135.539 R-Sq = 77.7% R-Sq(adj) = 76.5%

Regression Analysis: OT versus NCS, TTH, BO, LDR

The regression equation is
TOT = - 903 + 15.0 NCS - 0.000194 TTH + 10.7 BO + 0.0859 LDR

Predictor	Coef	SE Coef	T	P
Constant	-903.0	390.5	-2.31	0.025
NCS	14.955	1.792	8.35	0.000
TTH	-0.0001937	0.0001424	-1.36	0.179
BO	10.730	5.485	1.96	0.056
LDR	0.08586	0.05528	1.55	0.126

S = 136.942 R-Sq = 77.6% R-Sq(adj) = 76.0%

Regression Analysis: OT versus NCS, TTH, BO, ST

The regression equation is
TOT = - 743 + 14.8 NCS + 0.000213 TTH + 11.3 BO - 0.00416 ST

Predictor	Coef	SE Coef	T	P
Constant	-743.1	377.4	-1.97	0.054
NCS	14.822	1.630	9.10	0.000
TTH	0.0002131	0.0001737	1.23	0.225
BO	11.274	5.219	2.16	0.035
ST	-0.004157	0.001512	-2.75	0.008

S = 131.187 R-Sq = 79.5% R-Sq(adj) = 78.0%

Regression Analysis: OT versus NCS, TTH, LDR, ST

The regression equation is
TOT = - 55 + 15.3 NCS + 0.000172 TTH + 0.0447 LDR - 0.00373 ST

Predictor	Coef	SE Coef	T	P
Constant	-55.2	175.7	-0.31	0.755
NCS	15.309	1.747	8.76	0.000
TTH	0.0001724	0.0002126	0.81	0.421
LDR	0.04465	0.05998	0.74	0.460
ST	-0.003731	0.001724	-2.16	0.035

S = 135.955 R-Sq = 77.9% R-Sq(adj) = 76.3%

Regression Analysis: OT versus NCS, BO, LDR, ST

The regression equation is
TOT = - 815 + 14.9 NCS + 11.1 BO + 0.0540 LDR - 0.00285 ST

Predictor	Coef	SE Coef	T	P
Constant	-814.8	373.7	-2.18	0.034
NCS	14.899	1.660	8.97	0.000
BO	11.102	5.267	2.11	0.040
LDR	0.05396	0.04946	1.09	0.280
ST	-0.002849	0.001109	-2.57	0.013

S = 131.554   R-Sq = 79.4%   R-Sq(adj) = 77.9%

Regression Analysis: OT versus TTH, BO, LDR, ST

The regression equation is
TOT = - 747 + 0.000647 TTH + 20.6 BO + 0.193 LDR - 0.00532 ST

Predictor	Coef	SE Coef	T	P
Constant	-746.6	572.6	-1.30	0.198
TTH	0.0006470	0.0002972	2.18	0.034
BO	20.577	7.748	2.66	0.010
LDR	0.19255	0.08307	2.32	0.024
ST	-0.005323	0.002498	-2.13	0.038

S = 198.142   R-Sq = 53.2%   R-Sq(adj) = 49.8%

Regression Analysis: OT versus TTH, BO, LDR, ST, NCS

The regression equation is
TOT = - 762 + 0.000156 TTH + 11.0 BO + 0.0303 LDR - 0.00380 ST + 14.5 NCS

Predictor	Coef	SE Coef	T	P
Constant	-761.8	381.7	-2.00	0.051
TTH	0.0001562	0.0002066	0.76	0.453
BO	10.951	5.291	2.07	0.043
LDR	0.03032	0.05868	0.52	0.607
ST	-0.003795	0.001675	-2.27	0.028
NCS	14.525	1.739	8.35	0.000

S = 132.070   R-Sq = 79.6%   R-Sq(adj) = 77.7%

Appendix H

A Sample of Interviews Conducted at Damietta Port

Sample (1)

Interviewee : Port Director - Damietta port authority

Date : 21st August, 2007 Place : Damietta Port

س 1: عرفنا بنفسك وبدورك الوظيفى داخل الميناء؟

انه لتكريم وتشريف عظيم لى ان اكلف بقيادة ميناء متميز وواعد مثل ميناء دمياط وذلك بعد فترة عمل قاربت ثلاثة سنوات قضيتها نائبا لرئيس مجلس الادارة عايشت خلالها ادق تفاصيل مرحلة التطوير وكنت احد المشاركين فى ميكنة منظومة الميناء.

- Define yourself? And define your job description?

It's a great honor to me to be a chairman by a promising port like Damietta port. This was after the term of almost three years I spent as Vice Chairman of Damietta port. I experienced the finer details of the port development stage and I was one of the participants in the mechanization of the port system.

س 2: كيف ترى ميناء دمياط من الناحية الاستراتيجية كمدير للميناء؟

ميناء دمياط يتميز بموقعه الفريد بالقرب من قناة السويس ووقوعه بريا على الطريق الدولى الساحلى وشبكة النقل الداخلى وكذلك ر بطه نهريا بقناه ملاحية بنهر النيل وهو ما يطلق عليه شبكة النقل متعدد الوسائط. وعلى الرغم من حداثة الميناء وعمر القصير الذى لا يتعدى العشرين عاما الا انه يمتلك تاريخا قديما. لذا فقد جذب الميناء العديد من الاستثمارات .

- As a port chairman, how do you see the port of Damietta from the strategic point of view?

I see Damietta port is characterised by its unique location near the Suez Canal and it is close to the international coastal road. Also, the port is connected by different means of transport, namely river, road, railway and air. Despite the novelty of the port and the short life which does not exceed twenty years, but it has attracted many.

س3: هل تساعد تلك الاستثمارات على زيادة القدرة التنافسية للميناء؟

نعم

- Will these investment help to increase the competitiveness?

Yes of course

س4: كيف؟ وهل يمكن ذكر بعض تلك الاستثمارات؟

How do these investments can help to improve the port competitiveness?

- المشروع الضخم الذى تم توقيعه فى مايو 2006 لانشاء وادارة وتشغيل اكبر محطة حاويات فى حوض البحر المتوسط على مسطح حوالى 1 مليون متر مربع واستثمارات بقيمة 1 مليار دولار. سيساعد ذلك لتداول 4 مليون حاوية مكافئة بالمقارنة بالموانئ المجارة والمنافسة فى حوض البحر المتوسط.

- The large scale project, for example, which was signed in May 2006 for the establishment and management and operation of the largest container terminal in the Mediterranean Basin. The project in established on one million square meters and investment of $ 1 billion. This project will help to handle 4 million TEUs.

- مشروع محطة البضائع العامة والذى يهدف الى إقامة عدد 3 أرصفة بطول إجمالي 675 متر طولي وعمق 15 متر وساحة خلفية للرصيف بمسطح طولي 75 ألف متر مربع لإنشاء مستودعات أمامية وساحات. بالإضافة الي مساحة خلفية تقدر بمساحة 100.000 متر مربع لاقامة المخازن والساحات التخزينية والثلاجات والمباني الادارية. فيساعد ذلك على تداول وتخزين جميع أنواع البضائع العامة غير الملوثة للبيئة وكذا تصنيع وتعليب وتجميد المواد الغذائية تمهيداً لتصديرها.

- General cargo terminal project, which aims to establish three berths with total length 675 meters and a depth of 15 meters. It has also a back yard with 75 thousand square meters. This project helps in the circulation and storage of all types of general cargo as well as manufacturing and canning and freezing food prepared for export.

- مشروع السيارات حيث يتوفر لدى ميناء دمياط ساحة أسفلتية مجهزة تقدر مساحتها بحوالي 90 ألف متر مربع تقع بين رصيفي 8 , 9 وخلف رصيف الدحرجة الجنوبي بعمق 12 متر وكذلك رصيف البضائع العامة رقم 8. فيساعد ذلك لإقامة مشروع متكامل لتجميع وإعادة تصدير السيارات.

- Car Project, where there is the port of Damietta is equipped with asphalt yard area. It covers 90 thousand square meters located between 8 and 9 and southern ro-ro quay of 12 meters in depth. This helps to establish to establish an integrated project to assemble and re-export of cars.

Sample (2)

Interviewee : Operations Manager - Damietta port authority

Date : 7th October, 2009 *Place : Damietta Port*

س1: كيف يتم حساب وقياس الاداء لميناء دمياط؟ هل لديكم نظام قياس الاداء للميناء سواء من قبل الميناء او من قبل وزارة النقل او قطاع النقل البحرى؟

لا يوجد نظام قياس بمعنى نظام سواء كان الكترونى او يدوى ولكن يتم استخدام ما يسمى بمؤشرات الاداء والتى تساعد على اتخاذ الكثير من القرارات.

Q1: how do you calculate and measure the port performance of Damietta? Do you have a performance measurement system, either applied by the port or by the Ministry of Transport and the Maritime Transport Sector?

There is no system in the sense measurement system, whether electronic or manual, but we use of so-called performance indicators, which help to take decisions.

س2: كيف يتم ذلك؟ هل يمكن شرح ذلك بالتفصيل من فضلك؟

اولا يتم التركيز على عدد السفن المترددة واجمالى الطاقة المحققة فى قياس اداء المحطات والميناء ككل.فيتم استعراض عدد السفن والطاقة المحققة على مدار السينين وقياس اى زيادة او نقصان كمؤشر لبيان اداء الميناء. ونقوم بحساب الطاقة المحققة بالطن ويتم التركيز على كل من الحاويات والبضائع العامة. فعلى سبيل المثال انخفض اداء الميناء فى عام 2006 لتردد 1394 سفينة حاويات بالمقارنة بعام 2005 لتردد 1589 سفينة حاويات بمعدل تناقص -12%. اما فى سفن البضائع العامة تم تحسين الاداء بزيادة اعداد السفن فى عام 2006 الى 1638 سفينة بالمقارنة 2005 بتردد 1261 سفينة بزيادة قدرها 30%.

Q2: how is this done? Can you explain it in detail, please?

First, the focus is on the number of vessel calling the port and the total volumes handled, which are currently used in measuring performance of both terminals and the port as a whole. We 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. For example, the performance of the port declined in the year 2006 due to 1394 container vessels calling compared to 1589 container vessel calling in 2005, with decreasing rate by 12%. On the other hand, the port performance has improved by increasing the number of general cargo ships in 2006 into 1638 compared to 1261 ships in 2005, with an increasing rate by 30%>

س3: هلى يعنى ذلك انكم تعتمدون فى قرراراتكم (وقياسكم للاداء) على اعداد السفن واجمالى الطاقة المحققة فقط؟

Q3: does this mean that you rely on these indicators (a number of calls and total volume handled) in measuring a port performance?

نعم فيتم اتخاذ القررات وفقا للزيادة او النقصان فى اعداد السفن او الكيمات المتداولة.

Yes, decisions have been taken according to any increase or decrease in these indicators.

س4: ولكن هناك عوامل اخرى قد تؤثر على اداء الميناء؟

نعم، ففى عام 2005 انخفضت اعداد السفن بمقدار 20 سفينة ثم انخفاض حاد فى اعداد السفن فى عام 2006 بمقدار 195 سفينة وترجع للاسباب التالية:

- انسحاب خط الميرسك من ميناء دمياط الى ميناء شرق بورسعيد. فنسبة المساهمة فى عام 2004 بلغت 30% وانخفضت فى عام 2006 الى 2% فقط.
- شراء خط الميرسك لجميع اسهم خطى بى اند او وخط ند لويد وتوجيه سفنهم الى ميناء شرق بورسعيد
- توجيه 30% من سفن خط سى ام ايه الى ميناء بيروت بسبب عدم تناسب الغاطس امام الارصفة والتى لا تتناسب مع سفنهم العملاقة.

Q4: but there are other factors that influence port performance?

Yes, in 2005 the amount of ships decreased by 20 ships and then there was a sharp drop in 2006 by 195 ships. This was for the following reasons:

- The withdrawal of Maersk line of Damietta port calling East Port Said port.
- Maersk line has taken all shares of P&O line and NED Lloyd line and directed all their ships to East Port Said Port
- Re-directing 30% of ships owned by CMA line to Beirut Port due to inadequate depth in Damietta port for its new ships

س5: فهذا يعنى ان المؤشرات الحالية لقياس الاداء غير ملائمة او غير كافية؟

صحيح لانه لا يوجد نظام قياس اداء رسمى مطبق فى الموانئ المصرية، ونحاول النظر الى المؤشرات الاخرى. فننظر الى التفرقة بين الطاقة الاستعابية والطاقة الفعلية للمعدات وساحات التخزين بجانب اعداد السفن والكميات المتداولة (أ رافت) ولكن عند حسم الاداء يتم التركيز دائما على اعداد السفن والكميات المتداولة فقط لاعتبارهما اهم معايير اختيار الميناء للكثير من العملاء.

Q5: this means that the current indicators for measuring performance are not suitable or inadequate?

That's true. This is because there is no formal performance measurement system in place applied in Egyptian ports. This required looking at other indicators. We look at the capacity of handling equipment and storage yards, for example, next to the number of calls and total volume handled. However, a number of calls and total volumes are only be considered as the most important criteria in measuring performance because these indicators are being used by port clients in their selection of which port to call.

س6: هل هناك حاجة لنظام قياس اداء يعتمد علية؟

بالتاكيد، فوجود نظام يساعد على قياس الاداء سيساهم بشكل كبير وفعال الادارة العليا فى اتخاذ القرارات الاستراتيجية وهذا ما نحتاجه بالفعل فى الميناء.

Q6: is there a need to performance measurement system?

Certainly, the existence of a system helps to measure performance will contribute significantly in strategic decision making this is what we need.

س7: كيف تتم حساب الطاقة الفعلية للمعدات؟

انتاجية المعدات 25 حاوية مكافئة فى الساعة ويتم استخدام الحاوية المكافئة 20 قدم كمعيار لقياس انتاجية محطة الحاويات وكذلك نسبة اشغال الارصفة كما ذكر مسبقا.

Q7: how do you calculate the actual capacity of the equipment?

The productivity of equipment equivalent is 25 containers per hour and how many TEU handled is used in measuring the productivity of the container terminal as well as the occupancy rate of berths.

س8: لماذا دائما التركيز على الحاويات والبضائع العامة؟

لانهم اكثر البضائع تناولا واى زيادة او نقصان ستؤثر بالطبع على اداء الميناء.

Q8: why the focus in always on container and general cargo?

Because they are the most cargo handled in the port and any increase or decrease, of course, will affect a port performance.

س9: ولكن التركيز على نوع او اثنين فقط من البضائع لا يعنى ان يعكس اداء الميناء ككل؟

صحيح، اتفق معك

Q9: but the focus on one type of cargo does not reflect performance of port as a whole?

True, i agree with you

س10: نستطيع ان تقول ان هناك حاجة لنظام قياس الاداء للميناء ككل لكل انواع البضائع فى المحطات المختلفة بدلا من التركيز على نوعين فقط؟ كما ان هناك حاجة لزيادة معايير قياس الاداء لتشمل تلك العوامل المؤثرة على الاداء.

نعم صحيح وبذلك يساعد على فهم بعض الظواهر مثل اقلاع بعض الخطوط عن التردد على ميناء دمياط مثل ميرسك وب اند او وس م ايه والذى ادى ذلك لتدنى اعداد السفن المتردده على الميناء.

كما اتضح لنا ان احد مشاكلنا تتمثل فى القدرة الاستعابية الضعيفة للميناء لذلك قمنا بزيادة اعداد الارصفة والمساحات التخزينية كما ان مدخل الميناء ضيق لبعض انواع السفن حيث انه ذو اتجاه واحد. هناك العديد من العوامل التى يجب دراستها لمعرفية كيف تؤثر تلك العوامل على اداء الميناء.

Q10: can we say that there is a need for a performance measurement system that can be used to assess port performance as a whole for all types of cargo at different terminals, rather than focusing only on specific types of cargo? There is also a need to increase performance indicators to include those factors affecting performance?

Yes it is true and this will help to understand some phenomena such as why some shipping lines have left Damietta port like Maersk line, which led to lower number of calls. Also, we found that one of our problems is the capacity of the port. So, we increased the number of docks and storage areas. However, the port harbour entrance is narrow for some types of ships and it is one way. There are many variables that need to be studies and examined to see how they affect port performance.

س11: كما سبق وان قمت بشرح البحث الخاص بى والذى يهدف الى تطوير نظام قياس اداء فعال يساعد مديرى الميناء للتنبؤ بالاداء بالمستقبل والذى على اساسه يساعد فى اتخاذ القرارات اللازمه. كيف ترى

اشغال الارصفة مهم جدا حيث تدفع السفينة مبلغ 6 دولار لكل متر طولى للرصيف فى اليوم بالاضافة الى رسوم الميناء وتجبر اى سفينة على المغادرة اذا تجاوزت 16 يوم داخل الميناء وذلك تنفيذا للخطة الموضوعة من فبل وزارة النقل.

يجب التركيز على كل من:

- اشغال الارصفة
- المساحة الكلية والفعلية للمساحات التخزينية
- عدد وكفاءة المعدات والالات والاوناش
- معدل مكوث السفينة داخل الميناء

Q11: as i explained previously, my research aims to develop port performance measurement system that helps managers to predict port performance in the future. How do you see this?

Berth occupancy is important where a ship has to pay $6 per linear meter a day in addition to port dues and the port forces any ship to leave if it stays more than 16 days in the port. Time is crucial in measuring port performance. This will be in compliance with the plan set by the Ministry of Transport. Also, try to include:

- Berth occupancy
- Storage areas
- A number and efficiency of equipment and trucks
- Average stay of ships in the port

Sample (3)

Interviewee : Technical Office Manager - Damietta port authority

Date : 5th February, 2009 *Place : Damietta Port*

1 - يجب التركيز على اداء الميناء ككل بدلا من التركيز على الانتاجية لكل محطة على حدة. لذا يجب ان نرى الميناء على انه مجموعة من الانشطة فمنها ما يرتبط بالجزء البحرى ومنها ما هو مرتبط بالجزء البرى ومنها ما يرتبط بالمعدات والاوناش ومنا مها هو مرتبط بالتخزين ويجب الا ننسى الدور الحكومى والمتمثل فى الجمارك والذى قد يؤدى الى زيادة معدل مكوث البضائع داخل الميناء

2 - هناك حاجة لدراسة تلك العوامل المؤثرة على اداء المحطات على حده والميناء ككل. فوقت مكوث السفن ونسبة استخدام المعدات والاوناش المستخدمة فى عمليات الشحن والتفريغ ونسبة اشغال الارصفة وعدد احجام وساحات التخزين ونسبة استخدامهم وكذلك وقت مكوث البضائع فى الميناء، كلها عوامل تؤثر على اداء الميناء.

3 - تم ملاحظة وجود عدة ساحات تخزينية للبضائع العامة فمنها مخزن ثلاجة store fridge ومخزن مغلق closed store وصومعه silos وسقائف sheds.

4 - فحص البضائع الجافة وكذلك فحص معدات تفريغ البضائع السائلة قد يؤدى الى زيادة مدة بقاء البضائع والسفن داخل الميناء. لذلك يجب الاخذ فى الاعتبار وقت التعطيل للسفن سواء فى منطقة المخطاف او على الرصيف.

5 - وتقوم عدة شركات بعمليات الشحن والتفريغ مثل:

- شركة دمياط لتداول الحاويات والبضائع ولها اكبر نسيب من عمليات الشحن والتفريغ فلها للحاويات عدد 8 اوناش عملاقة متحرك على قضبان و10 ونش ساحة حمولة 43 طن و 40 ونش ساحة حمولة 17 طن وعدد 17 شوكة ساحة حمولة 40 طن اما للبضائع العامة عدد 9 ونش و13 شوكة.
- شركة النجاح
- شركة بدرى فخرى
- شركة كايرو ثرى
- شركة ستيوترانس
- شركة الشروق
- شركة السنابل
- الشركة البحرية
- شركة المعدية

1- There is a need to focus on measuring performance of the port as a whole rather than focusing on productivity for each terminal separately. We must see port as a set of activities, some of which are associated with maritime side and some are linked to land side. Other activities are linked to storing cargo and other are linked to equipment and handling methods. Also, we cannot forget the role of government, which could lead to increase the period of time a ship and cargo stay in port, such as in case of customs. All these activities should be included in such a system.

2- There is a need to study these variables affecting terminals' performance. The time for stay of ships, the percentage of use of handling equipment used in loading and discharging operations, the occupancy rate of storage yards and the time cargo stay in the port, are all variables that affect port performance.

3- It is observed that there are several storage yards for general cargo including refrigerated store, closed store, silos and sheds.

4- Inspection required for dry bulk and testing equipment before, during and fter loading and discharging liquid bulk lead to increase the duration of cargo stay inside port. It is important to take into consideration standing time of ships whether in anchorage area or at berths.

5- There are several companies are responsible for loading and discharging, including Damietta container and cargo company that has larger cousin of operations. It has for handling containers 8 cranes moving on rail and 10 winches with capacity 43 tonnes and 40 winch yard with load capacity 17 tonnes and 17 forklifts with capacity 40 tonnes. For general cargo, it has 9 cranes and 13 forklifts. There are other companies that handle different types of cargo including:

- Al-Badri-Fakhry Company
- Al Nagah company
- Cairo Three Company
- Stiotrans company
- Sunrise company
- Al-Sanabel company
- The company's marine

- Al-Madia company

س 1: ماذا عن نسبة اشغال الارصفة ومعدلات انتاجية الارصفة فى المحطات المختلفة داخل الميناء؟ ذكر مدير الميناء انه يتم اتخاذ تلك المؤشرات فى الحسبان عند قياس اداء الميناء. كيف يتم ذلك؟

Q1: what is about the berth occupancy and production rates at different terminals? Can you explain to me how do you use these indicators in measuring port performance?

يتم الاهمام بحساب نسبة اشغالات ارصفة الحاويات وارصفة البضائع العامة حيث تشير الى عدد الايام الغعلية الى شغلت فيها السفن هذه الارصفة وبالتالى يتم اتخاذ القرار ما اذا كانت هناك حاجة الى بناء ارصفة جديدة ام لا. فاذا ما نظرنا الى انخفاض نسبة الاشغالات من 84% فى عام 2004 الى 72% فى عام 2006 ثم بالزيادة الى 81% فى عام 2008. هذا ما دعانا الى بناء رصيفين جديدين ليكون الاجمالى 18 رصيف بدلا من 16 رصيف. فارتفاع معدلات اشغالات الارصفة يدل على ارتفاع معدلات التفريغ والشحن وسيولة الحركة بالميناء.

- We calculate berth occupancy at container terminal and general cargo berths, which both refer to how many days occupied by calling ships. Consequently, decisions are made to build new berths or not. In 2004, berth occupancy decreased into 84% compared to 72% in 2006, and then it has increased again into 81% in 2008. This explains why new two berths were built to make total berths 18 berths instead of 16 berths.

ولكن يجب ملاحظة ان ارتفاع معدلات الاشغالات لبعض الارصفة غير حقيقية. فمثلا، ارتفاع نسبة اشغال ارصفة الغلال نظرا لاستخدامها فى تفريغ وشحن سفن البضائع العامة فى حالة خلو هذه الارصفة من سفن القمح وهو احد الحلول الذى اعتمدته الادارة لاستخدام ارصفة الميناء الاستخدام الامثل ولتقليل فترات انتظار السفن للشحن او التفريغ.

- However, it is important to observe that berth occupancy for some berths are not true. For example, dry bulk berths are sometimes in use for loading and discharging general cargo ships when there are no wheat ships. It is one of the solutions adopted by port managers to make optimal utilisation of available berths in order to reduce waiting times for ships or cargo.

كما ان ارتفاع نسبة اشغال الارصفة قد يكون بسبب ارتفاع عدد السفن مما يزيد من عدد ساعات الانتظار الخارجى للسفن فى منطقة المخطاف والذى قد يصل الى 36 ساعة فى حالة سفن البضائع العامة. وهذا قد يؤثر على مستوى اداء الميناء وبالتالى قد يقلل من عدد السفن والكميات المتداولة بالميناء وقد حصل بالفعل.

The high occupancy rate may be due to high number of calling ships, which increase waiting time for ships in anchorage area into 36 hours in case of general cargo ships. This may affect the level of performance of the port and thus may reduce the number of vessels and the quantities traded through the por. And it has happend.

س 2: كيف حصل ذلك؟

فاذا ما نظرنا الى كميات البضائع العامة الواردة للميناء طبقا لانواع السفن فسنلاحظ تدنى فى الكميات الواردة، فمثلا انخفضت نسبة الحبوب فى عام 2000 من 56% الى 26% فى عام 2007 وكذلك الاخشاب. اما فى الحديد فالكميات انخفضت من 18% فى عام 1999 الى 8% فى عام 2006.

Q2: how did this happen?

If we observe the quantities of goods imported to the port, we observe a decline in total volumes handled at the por. For example, grain volumes decreased from 56% TO 26% in 2000, as well as wood. Also, the iron quantities decreased from 18% in 1999 to 8% in 2006.

س3: هل نستطيع ان نلخص القول بان ارتفاع نسبة اشغال الارصفة والذى قد يرجع الى عوامل كثيرة من معدلات الشحن والتفريغ قد ادى الى زيادة فترة بقاء السفينة فى الميناء سواء فى منطقة المخطاف او على الرصيف وبالتالى ادى الى عدم ارضاء الكثير من السفن التى اثرت ان تردد على ميناء دمياط البحرى؟

نعم بالفعل

Q3: can we say that high occupancy rate is influenced by many factors such as loading and discharging rate, waiting time in anchorage area or at berths, etc. These factors may lead to increase length of stay of ships in the port. Subsequently, this led to dissatiasfy port users and led to call other ports.

Yes of course

س4: هل تتفق معى انه يجب عدم التركيز على الحاويات والبضائع العامة فقط عند قياس اداء الميناء؟

نعم بالتاكيد فعدد السفن المترددة على الميناء للبضائع الاخرى فى تزايد مثل سفن الحبوب والتى وصلت الى 175 سفينة فى عام 2004 وتم تداول 5.14 مليون طن سنويا. كم ان هناك زيادة فى سفن القمح خاصة المترددة لصالح القطاع الخاص. وبالنسبة للقمح، يتم الاستيراد لصالح الهيئة العامة للسلع التموينية طبقا لبرامج محددة من حيث الاستيراد ومن حيث صرف الاقماح من صومعة ميناء دمياط.

و بتحليل الاعداد والكميات المتداولة لتلك النوعيات من السفن على سبيل المثال يوضح ان هناك حاجة الى عدم التركيز على الحاويات والبضائع العامة فقط ما اذا اردنا قياس اداء الميناء ككل.
فالحاصلات الزراعية تمثل عنصرا هاما من طاقة الميناء والتى تمثل العدس والفول والتفاح والموز والذى وصل اجمالى الوارد الى 218992 طن فى 2007 بدلا من 49346 طن فى 2000.

- Do you agree with me that managers should not focus on containerised cargo and container terminal in measuring port performance?

Yes, certainly as the number of calling ships of other types of cargo is growing over the years, such as grains, which has reached to 175 ships in 2004 that handled 5.14 million tonnes annually? Also, demand has increased on wheat that is imported for the benefit of the General Authority for Supply Commodities. Analysing these numbers traded of other types of cargo requires not focusing on containerised cargo when measuring port performance as a whole. Agriculture products is also important type of cargo including lentils, beans, apples and bananas, which increased into 218992 tonnes in 2007 compared to 49346 tonnes in 2000.

Appendix I

A Snapshoot of the Regression Spreadsheet